Atlantic Salmon (Salmo salar) of the Big Salmon River, New Brunswick

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ABSTRACT

Jessop, B.M. 1986. Atlantic salmon (Salmo salar) of the Big Salmon River, New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. No. 1415. xii + 50 p.

Counts and biological information on the Atlantic salmon returning to the Big Salmon River fence were obtained annually between 1964 and 1973. Supplementary data were provided by surveys of the angling catch. Annual fence-trap counts ranged from 218 to 4,636 fish. Run duration extended from June to November with the peak in August-September. The stock consists essentially of previous, consecutive-spawning, 1-sea-winter fish; 93 percent of fish matured after one sea-winter, 7 percent after two sea-winters. On average, about 50 percent of the count consisted of virgin 1-sea-winter fish, but wide fluctuations occurred between years. Angling catches may not produce reliable estimates of the proportions of large salmon and grilse in the run, although reliable estimates of sex and length composition may be derived. Simpson's paradox may occur in the analysis of several years of variable data. Growth rates declined progressively with age and frequency of spawning. Females grew more slowly with repeated spawning than did males, yet attained a larger ultimate size because they lived longer. The contribution of previous, consecutive-spawning, 1-sea-winter stocks to the relationship between age at smoltification and sea-age upon return to the river is discussed. Egg-to-smolt survival rates averaged 0.17 percent.

Key words: Atlantic salmon, Big Salmon River, annual fence-trap count, run timing, size, sex composition, freshwater age, sea-winter age, consecutive-spawning, growth rate and survival rate.

RÉSUMÉ

Jessop, B.M. 1986. Atlantic salmon (Salmo salar) of the Big Salmon River, New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. No. 1415. xii + 50 p.

De 1964 à 1973 on a dénombré chaque année les saumons de l'Atlantique qui sont retournés à la barrière de la rivière Big Salmon et l'on a recueilli des données sur leurs caractéristiques biologiques. Les relevés de la pêche sportive nous ont apporté des données additionnelles. La valeur des dénombrements annuels a varié de 218 à 4636 poissons. La remonte a lieu de juin à novembre; elle est maximale pendant la period d'août à septembre. Le stock comporte surtout des poissons précoces, à frayes multiples, ayant passé un hiver en mer; 93% des poissons

atteignent la maturité après un hiver en mer, 7% après deux hivers. En moyenne, environ 50% des poissons dénombrés étaient des sujets vierges ayant passé un hiver en mer, mais il y a eu d'importantes fluctuations d'une année à l'autre. Les prises de pêche sportive ne permettent pas nécessairement d'estimer de façon fiable la proportion de saumons de grande taille et de madeleineaux que comporte la remonte, mais on peut s'en servir pour faire une estimation représentative de la composition par longueur et par sexe. L'analyse de variables mesurées en plusieurs années peut mettre en évidence un paradoxe de Simpson. Le taux de croissance baisse progressivement avec l'âge et la fréquence des frayes. Les femelles qui fraient plusieurs fois se développent plus lentement que les mâles, mais elles deviennent plus grosses, car elles vivent plus longtemps. On examine comment les stocks de poissons précoces, à frayes multiples, ayant passé un hiver en mer influent sur la relation entre l'âge à la smoltification et l'âge en mer au moment de la remonte. Le taux de survie des oeufs jusqu'à la smoltification est en moyenne de 0,17%.

INTRODUCTION

The Big Salmon River, New Brunswick (Fig. 1), was historically regarded as an excellent producer of Atlantic salmon (Salmo salar), but during the mid-1800s the river was dammed by sawmills and no salmon spawned there (Perley 1852). The mills were later closed and the dam was breached, leading to a restoration of the salmon run. During the 1920s, the river was dammed again by the Pejepscot Paper Company to create a log storage pond, and the revived salmon run declined markedly. Rehabilitation of the stock began in the early 1930s with construction, through government assistance, of a fishway at the tide-head logging dam and provision of warden protection for the subsequently increasing salmon run. The dam and fishway were removed in 1963. Between 1938 and 1969, hatchery-reared juvenile Atlantic salmon of various ages and stock origins were periodically released into Big Salmon River with the initial intent of assisting in rehabilitation of the stock and later for experimental purposes (Annual Reports, Dept. of Fisheries 1938-65; Jessop 1976). Rainbow trout (Salmo gairdnerii) were also periodically released into the river between 1944 and 1957. After some initial success in establishing a spawning population, decline set in, and by the early 1970s, rainbow trout returning to the counting fence were rare.

In 1964, a 10-year study of the river's Atlantic salmon stock began with installation of a counting fence near tide head. Initially, the study was part of a larger study of early- and late-run salmon stocks in selected Maritime rivers. These studies later evolved to include collection of data on size and timing of smolt and spawning runs, adult and juvenile age and growth characteristics, parr distribution and density, angler harvest, and tagged fish recapture. The ultimate objective became a cohesive study of the long-term dynamics of a salmon population in a small river. Such a project was expected to yield insights into salmon biology of fundamental value as well as management advice for this and other salmon rivers, but the project was discontinued prior to the completion of data collection on even two salmon

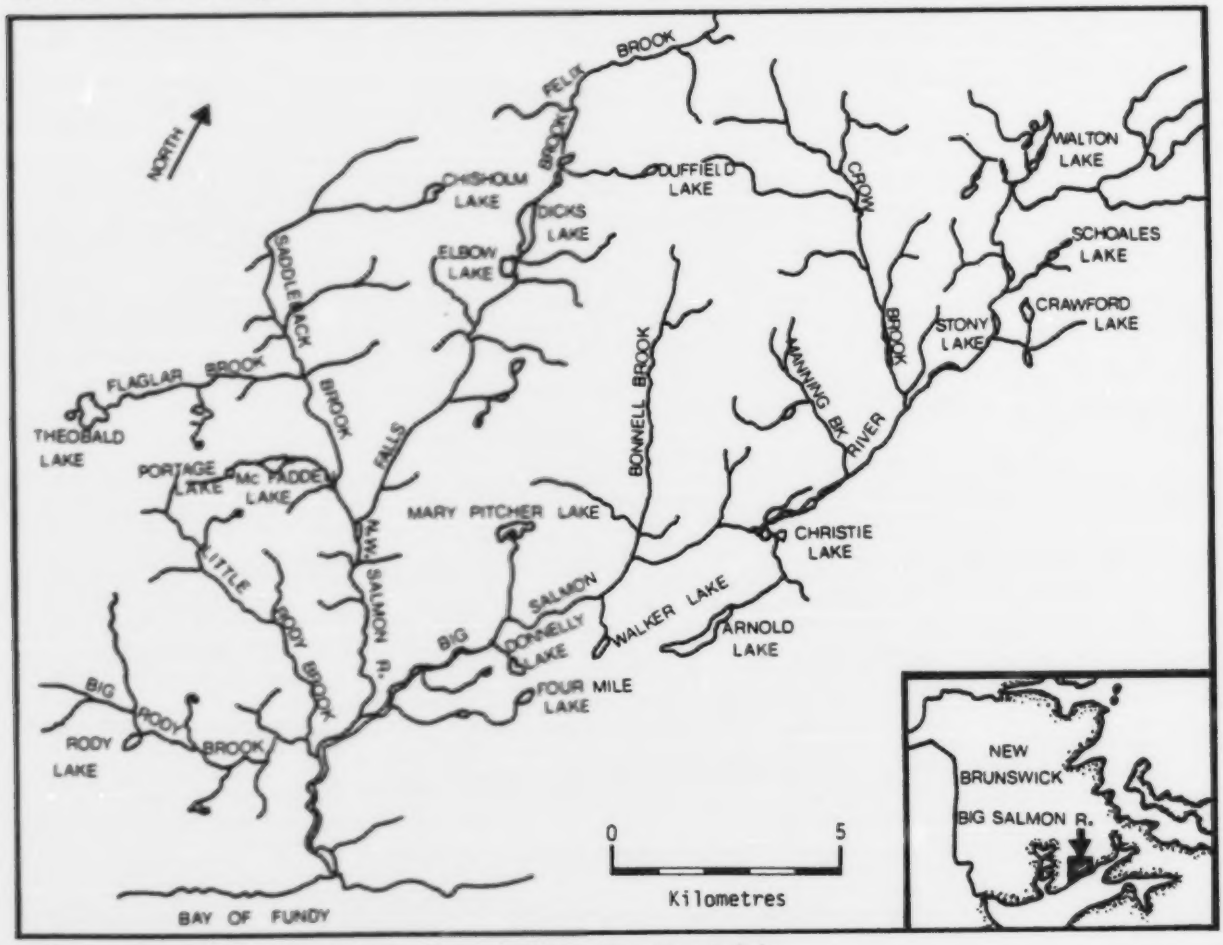

FIG. 1. Map of the Big Salmon River system, New Brunswick.

generations.

This report summarizes adult salmon data collected between 1964 and 1973 and discusses aspects of the fish's life history. Detailed information is limited for stocks with life histories similar to that of Big Salmon River salmon, (White and Huntsman 1938; Dadswell 1968; Saunders 1981; Semple, pers. comm.[1]). Terminology for the various life stages of Atlantic salmon follows Allan and Ritter (1977).

The smolt run in Big Salmon River has been discussed by Jessop (1975) as has the marine distribution of salmon, as indicated by tag recoveries (Jessop 1976).

DESCRIPTION OF THE STUDY AREA

The following description of the river system has been extracted primarily from Jessop (1975).

The Big Salmon River drains an area of approximately 332 km and discharges into the New Brunswick side of the Bay of Fundy at 45°25'N (Fig. 1). When all tributaries are included, there are approximately 127 km of stream; the main stem extends about 27 km from Walton Lake to the mouth. The river flows in a generally southwesterly direction for most of its length, while the lower 3 km flow more southerly.

From Walton Lake to its mouth, the Big Salmon River falls about 218 m in elevation (Fig. 2). The upper portion of the river, from Walton Lake to just below the junction with Arnold Brook (Fig. 1), has a slope of about 2 m/km. As Bonnell Brook is approached, the gradient changes abruptly and a descent of over 6 m/km begins and continues to within several kilometres of the mouth, where the slope again decreases. The middle and lower

1. Semple, J.R. 1984. Biologist. Freshwater and Anadromous Division, Fisheries Research Branch, Dept. of Fisheries and Oceans, Halifax, Nova Scotia.

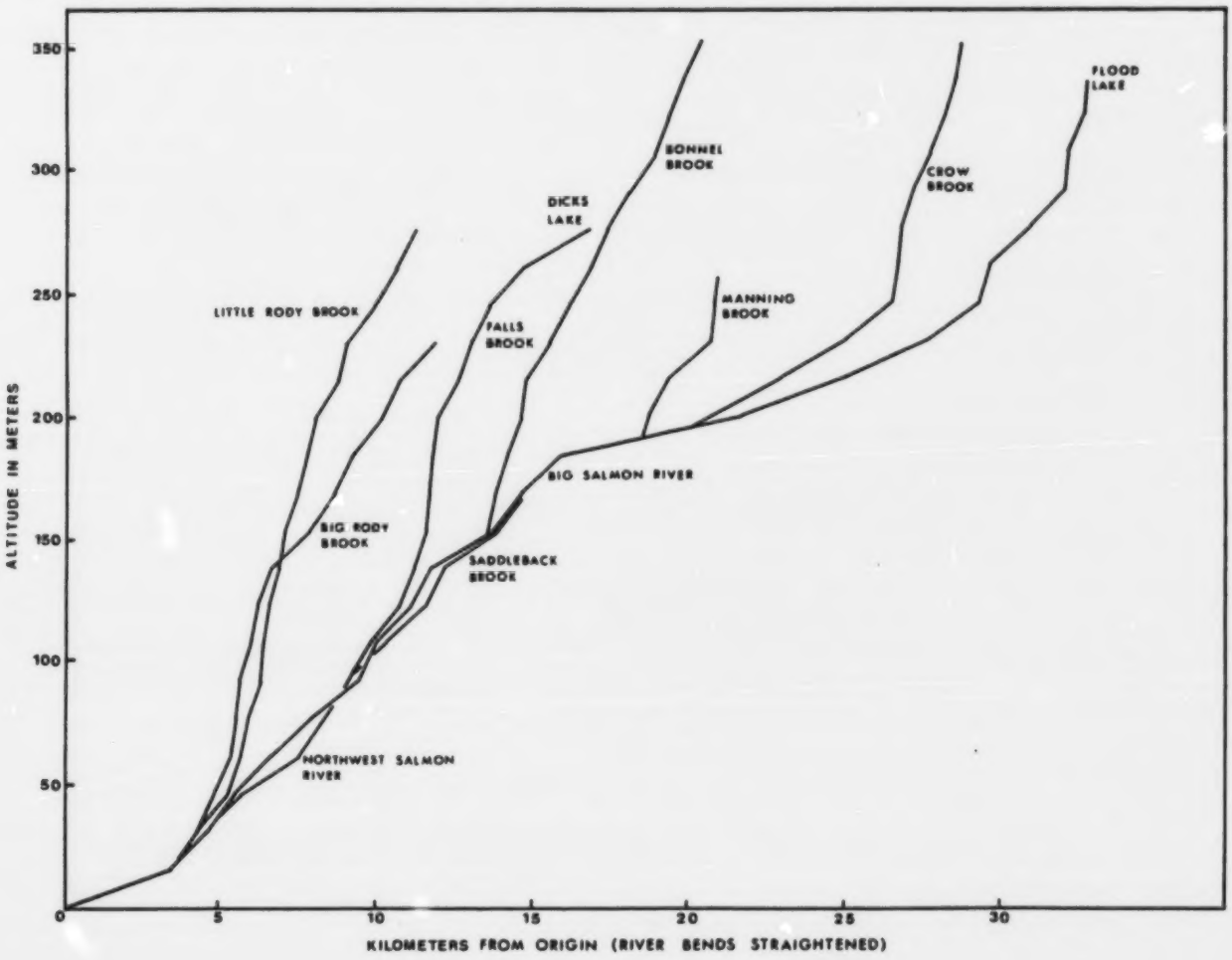

FIG. 2. Stream gradients of Big Salmon River and tributaries.

sections contain numerous rapids and riffle areas and are closely bounded by hills rising steeply 90 m-125 m.

An estimated 464,900 m^2 of stream rearing area are accessible to salmon, while a further 144,544 m^2 are inaccessible (Redmond 1971[1] and Dept. of Fisheries survey 1971 [Unpublished]). Approximately 15,700 m^2 are suitable and available for spawning.

Smith (1955)[2] and Kiley (1970)[3] provide further details on the physical features of the river system, particularly obstructions and salmon spawning and rearing areas.

The river flows through areas of sedimentary, volcanic and igneous rock (Aalund and Wicklund 1949). Loams of several types (generally sandy or gravelly) predominate and overlay glacial till of mainly non-calcareous composition. They note that "the climatic conditions prevalent in New Brunswick favor the development of acid-leached soils known as podsols, and favor the growth of coniferous trees and the accumulation of organic material on the surface of the soil."

Water quality data for the river were first systematically collected in 1970. Sixteen monthly samples were collected between December 1970 and June 1972. The mean pH was 6.3 (range 5.8-6.6); mean total hardness was 7.0 ppm (range 4.9-8.3); and mean specific conductance was 26.8 siemens cm^{-1} (range 20.9-30.6). Concentrations of heavy-metal ions were negligible. Adequate levels of dissolved oxygen for salmonids should be assured at all times by the swift and turbulent flow of the river. Redmond (MS 1971) reports that the surface pH of Walton Lake was 6.9 when sampled, the total hardness was 15.1 ppm, and the specific conductance at 25°C was 35.8 siemens cm^{-1}.

Water discharge and temperature data were first collected from a gauging station in 1971. Between 1971 and 1978, the mean annual discharge was 11.8 m^3s^{-1} (range 9.1-15.0 m^3s^{-1}). Seasonal peak discharge occurred in April-May (period mean 23.5 m^3s^{-1}) and October-December (period mean 13.6 m^3s^{-1}), with low discharges in January-February (period mean 8.7 m^3s^{-1}) and July-September (period mean 5.4 m^3s^{-1})(Anon. 1980). The mean ratio of annual maximum/minimum monthly discharge was 6.1. The largest ratio of daily maximum/minimum discharge was 141.2 in 1973 while the maximun daily discharge of 140 m^3s^{-1} occurred in 1972. Water temperatures average about 1.0°C between January and late March or early April, after which they rise irregularly, reaching 10°C between mid-May and early June, peaking at 20°-22°C between late June and late August, then decreasing below 4°C by early to late November (Anon. 1976).

DESCRIPTION OF THE COUNTING FENCE

The counting fence was of A-frame construction, about 48.8 m long and set at an angle of about 13° to the river flow (Fig. 3). It had the capacity to screen the whole river discharge except during peak flows, (exceeding about 1.4 m on the staff gauge). Its location about 180 m upstream of tide head enabled a virtually complete enumeration of salmon returning to the river. Following the smolt migration (late June or early July), the smolt racks were removed and replaced with salmon racks, constructed of a wood frame inset with 2.5-cm x 10-cm wood slats on 5.6-cm centers and fitted between I-beam grooves on the upstream face of each A-frame. The adult trap was located at the true right bank of the river and was of different design, in accordance with its function, than the smolt trap located at the opposite shore. Both traps could be operated simultaneously if circumstances required it. The fence usually remained in operation until late October or early November, at which time the run had virtually ceased, i.e., no fish recorded for periods of 3-4 days. Occasionally, periods of high water forced removal of some racks, thus temporarily disrupting the salmon count.

STUDY METHODS

During the spawning run, the trap was checked several times daily, beginning about 0800 hours. All salmon passed through the trap were processed - scanned for marks or tags, sexed by criteria based on head conformation and size, and classified as large salmon (multi-sea-winter [MSW] fish) or grilse (1-sea-winter [1-SW] fish). A representative subset, varying in size from year to year, was measured for fork length, weighed and scale sampled. The methodology of data collection evolved such that: (a) From 1964 to 1967, the fork lengths of about 5 percent (range 3-7 percent) of untagged salmon were measured to the nearest inch but no weights were recorded. Fish under 25 inches (63.5 cm) long were classed as grilse. (b) From 1968 to 1970, varying numbers of fish (23-46 percent of return) were measured for fork and total lengths, to the nearest 0.5 inch in 1968 and to the nearest 1.0 cm in 1969 and 1970. Fish

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1. Redmond, M.A. 1971. Biologist. N.B. Dept. of Natural Resources Fish and Wildlife Branch. Fredericton, N.B. (MS report. unpublished.)

2. Smith, K.E.H. 1955. Biologist. Dept. of Fisheries, Fish Culture Development Branch, Saint John, New Brunswick. (MS report, unpublished.)

3. Kiley, T. 1970. Technician. Dept. of Fisheries and Forestry, Resource Development Branch, Halifax, Nova Scotia (MS report, unpublished.)

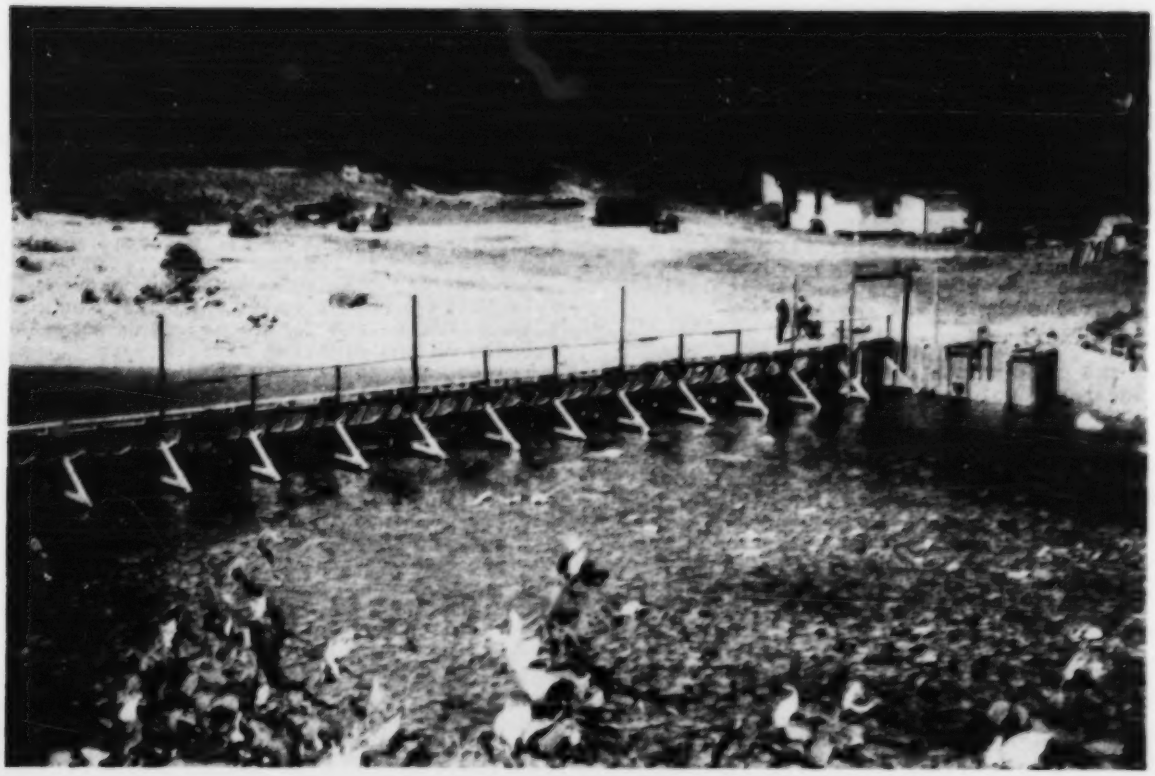

FIG. 3. Salmon counting fence, Big Salmon River, New Brunswick. (Adult trap is on true right bank of river and out of photograph.)

were weighed to the nearest 0.25 lb (0.1 kg) in these years. Fish under 5 lb (2.3 kg) were considered to be grilse. (c) From 1971 to 1973, most fish had fork and total lengths measured to the nearest 1.0 cm and weights taken to the nearest 0.02 kg. All Imperial measurements have been converted to metric for use in this report.

Weight-length relationships were estimated with geometric mean (GM) regressions (Ricker 1973) based on up to 30 fish per 2-cm fork-length interval, randomly selected from the range of lengths available for each of four categories based on sex and age at maturity. For the total data set, the length bounds ranged from 42 cm to 100 cm. Conversions between fork and total lengths can be made by using the geometric mean regression equation $Y = -0.980 + 0.980\ X$, where Y = fork length, X = total length, $n = 417$, $r^2 = 0.994$ and $s'_{y \cdot x} = 0.947$. Up to ten fork-length/total-length pairs were chosen per 1-cm fork-length interval in the range 46 cm-89 cm.

Population data based on the separation of multi-sea-winter salmon from grilse by weight differs somewhat from those based on scale age data. When the terms large salmon and grilse are used, they will refer to fish classified by weight or generically, according to the context; when sea-winter ages are used, they are based on scale age interpretation.

Analyses of variance (one-way) were used to examine differences between: (1) mean lengths and weights of salmon between years, by age-group and sex, (2) mean monthly lengths and weights of salmon returning to the counting fence, (3) lengths and weights, within years, of 1- and 2-SW virgin salmon of each sex, (4) lengths, within years, of 1-SW virgin and multi-sea-winter salmon collected at the counting fence and in the angling fishery, (5) age at smoltification, within and between years, of 1- and 2-SW virgin salmon. Two-way analyses of variance were used to examine differences between years in the lengths and weights of 1- and 2-SW virgin salmon of each sex. Analysis of covariance was used to examine the relationship between weights and lengths according to sex and age at maturity. Tests of the equality of two percentages were used to compare the percentage of large salmon and grilse caught by the angling fishery and at the counting fence.

Heterogeneity of salmon length and weight sample variances was significant ($P < 0.001$; Bartlett's test) between years and distributions were often non-normal. No relationship was found between means and standard deviations and it was considered unnecessary to transform the data. Fortunately, most parametric statistical analyses tend to be robust in

response to violations of assumptions if they are based on a large number of error degrees of freedom (Harris 1975), a condition that is met here in most cases. The consequences of moderate non-normality of error and heterogeneity of variances are not serious for overall F-tests as used in analyses of variance.

Scale samples (8-10 scales per fish) were removed from an area several rows above the lateral line and immediately posterior to the base of the dorsal fin. Standard methods were used in the interpretation of scale ages (White and Medcof 1968; Ducharme 1969).

Maximum and minimum water temperatures were recorded daily at the counting fence, usually at 0800 hours; water levels were recorded each time the trap was checked. In July 1971, water temperatures became available from a gauging station several hundred metres upstream of the counting fence and in December, water discharges became available (Environment Canada, Inland Waters Directorate).

For many years, counting-fence staff and resident fish wardens kept records of variable completeness of the numbers, lengths and weights of salmon angled in the river during the May 15-October 15 fishing season. Records were most complete during the 1970s when considerable effort was given to creel surveys. Beginning in 1964, a distinction was made as to whether fish were large salmon or grilse and, since 1966, whether they were angled above or below the counting fence. The sex of many angled and some fence-caught fish was confirmed by examination of the gonads.

Records were maintained on all tagged fish released into and returning to the Big Salmon River. Jessop (1976) summarized much of this information. In 1970, 63 salmon were collected for hatchery egg requirements, tagged and subsequently released into the river; in 1971, a group of salmon was gill-netted, tagged and released off the mouth of the Big Salmon River; in 1972, 190 grilse were tagged and released at the counting fence.

RUN TIMING AND COMPOSITION

The Big Salmon River has a late summer run of Atlantic salmon. Although the first fish may arrive in late May and the last in mid-November, about 76 percent of the run occurs during August and September, with the peak between mid-August and mid-September (Table 1). A clear correlation is evident between sharply rising water levels and increased counts of salmon at the fence during most of the salmon run (Appendix Figs. 1-10). The magnitude of the increase in fish count was better related to the degree of completion of the run and the availability of fish than to the degree of rise in water level. Consequently, a modest increase in water level during the middle of the run brought more fish to the fence than a sharp rise at the beginning or end of the run. Water temperature evidently had little influence on the magnitude of the fence count during most of the run, although the first appearance of a small group of fish occurred at about 16°C, with final appearance at 9°C.

Salmon returns to the counting fence varied from 218 in 1973 to 4,636 in 1966. In some years, floods breached or overflowed the fence, thus permitting uncounted fish upriver. Estimates of these uncounted fish are available in some years but have not been included in counts unless otherwise indicated. The fence count thus provides a minimal total of fish returning to the river. A more accurate and larger total is obtained by adding to the fence count the angling catch downstream of the fence. Estimates of spawning escapement obtained by subtracting the angling catch upriver of the fence from the fence count ranged from a minimum of 0 fish in 1973 to 4,447 fish in 1966. The spawning escapement is underestimated when floods result in uncounted fish moving upstream. A more accurate escapement is obtained by adding on an estimate of the uncounted fish, based on an estimate of the fish downriver of the fence prior to the flood. Thus, in 1973, an escapement of 671 fish seems more realistic than 0 fish, although great confidence cannot usually be placed in estimates of the number of fish moving upriver of the counting fence during a flood (Table 1).

The monthly proportions of large salmon and grilse at the counting fence varied considerably between years but, averaged over all years, were similar (Table 2). On an annual basis, the proportions of large salmon and grilse fluctuated markedly, with grilse forming 14.8 percent of the fence count in 1969, 68.6 percent in 1972 and averaging 46.0 percent over all years (Table 2 and Fig. 4).

AGE, SIZE AND SEX COMPOSITION

Large salmon from the Big Salmon River are essentially previous, consecutive-spawning, 1-sea-winter fish. The proportion, according to scale-age, of one-sea-winter, virgin fish returning to the counting fence varied greatly between years, from 3.9 percent in 1969 to 90.5 percent in 1972, but averaged about 50 percent (Table 3). Virgin spawners were about 93 percent 1-sea-winter and 7 percent 2-sea-winter fish. One-sea-winter fish contributed from 28 to 99 percent of the total annual return of 1- and 2-sea-winter virgin fish. Proportions of 1-sea-winter fish less than 90 percent occurred in only two of ten years and only when returns of virgin fish were very low.

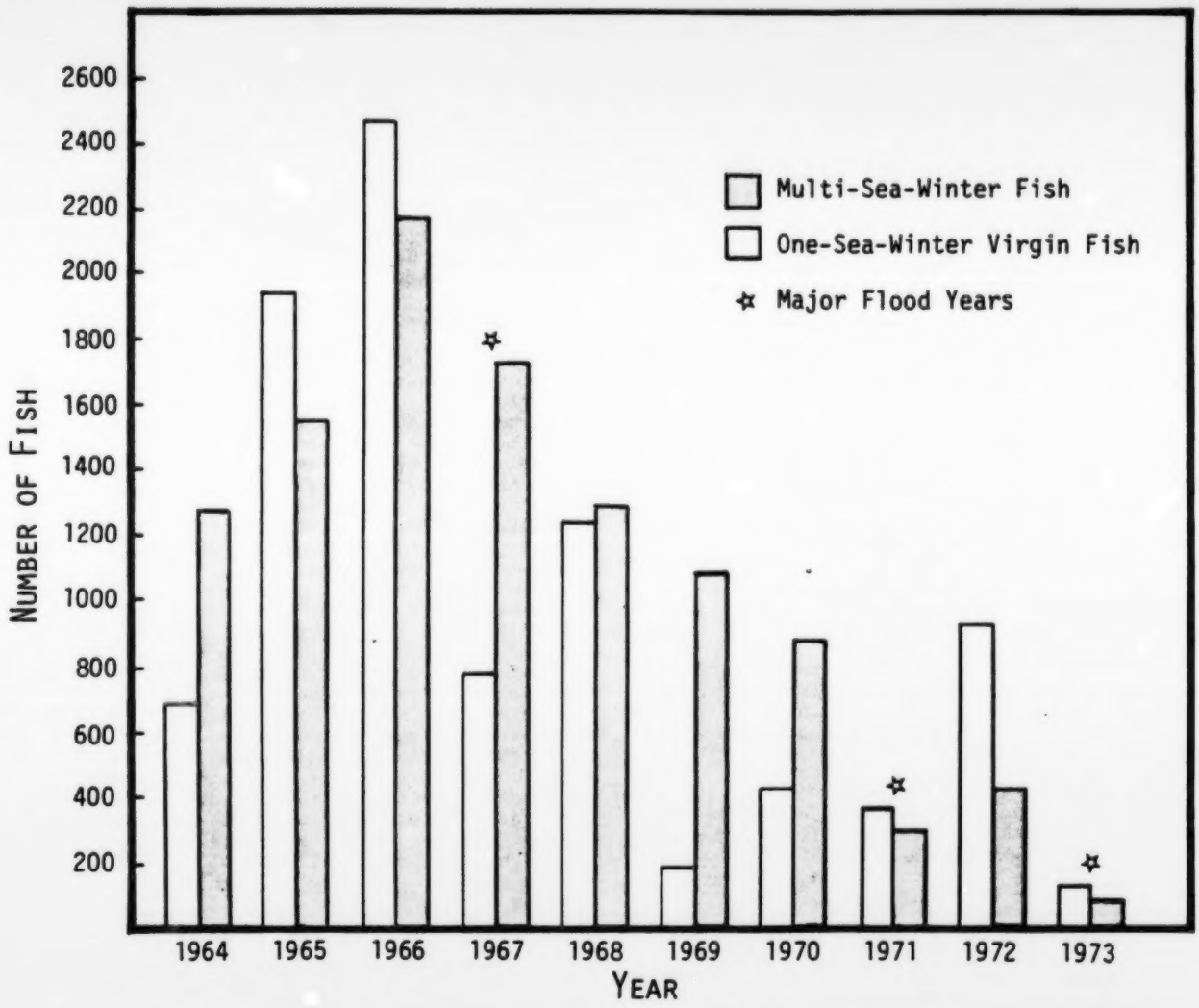

FIG. 4. Annual counts of large salmon and grilse at the Big Salmon River fence, 1964-73. (Counts during flood years underestimate the actual return.)

Virgin 3-sea-winter fish were rare (< 0.2%). Fish with two to four spawning marks on their scales were relatively common, but one fish displayed seven spawning marks and was thus embarking on its eighth spawning run. Length-frequency distributions of fish at various ages were approximately normal (Fig. 5).

The use of weight as a separation criterion overestimated the proportion of grilse based on scale age when the proportion of 1-SW virgin fish was low (< 25 percent); otherwise it underestimated the proportion of grilse (Table 4). The mean absolute difference between scale-age and weight categorization was 9.4 percent (range 1.8-21.9 percent). Based on five years of data, about 6.4 percent of multi-sea-winter salmon weighed < 2.3 kg, thus confirming the overestimation by the weight method of the true proportion of 1-SW virgin salmon. A few (<1 percent) 1-SW virgin fish weighed > 2.3 kg.

Anglers caught 8.2 percent fewer large salmon on average and more grilse than might be expected, based upon the percentages of grilse and large salmon in the fence count (Table 5). Since no significant difference ($t_{1,4}$ = 0.84, $P > 0.40$) was found between the proportions of large salmon and grilse angled either upstream or downstream of the counting fence, it was decided to compare the proportions of all angled large salmon and grilse with those recorded at the counting fence rather than only with data on the composition of fish angled upriver. Within-year absolute differences in the percentage of grilse (and large salmon) in the angling catch compared with those in the fence count ranged from -14 to 27 percent. Further examination of the proportions of salmon and grilse in the angling catch and in the fence count indicated significant heterogeneity between years in both angling catch (X^2_4 = 561.3; $P < 0.001$) and fence count

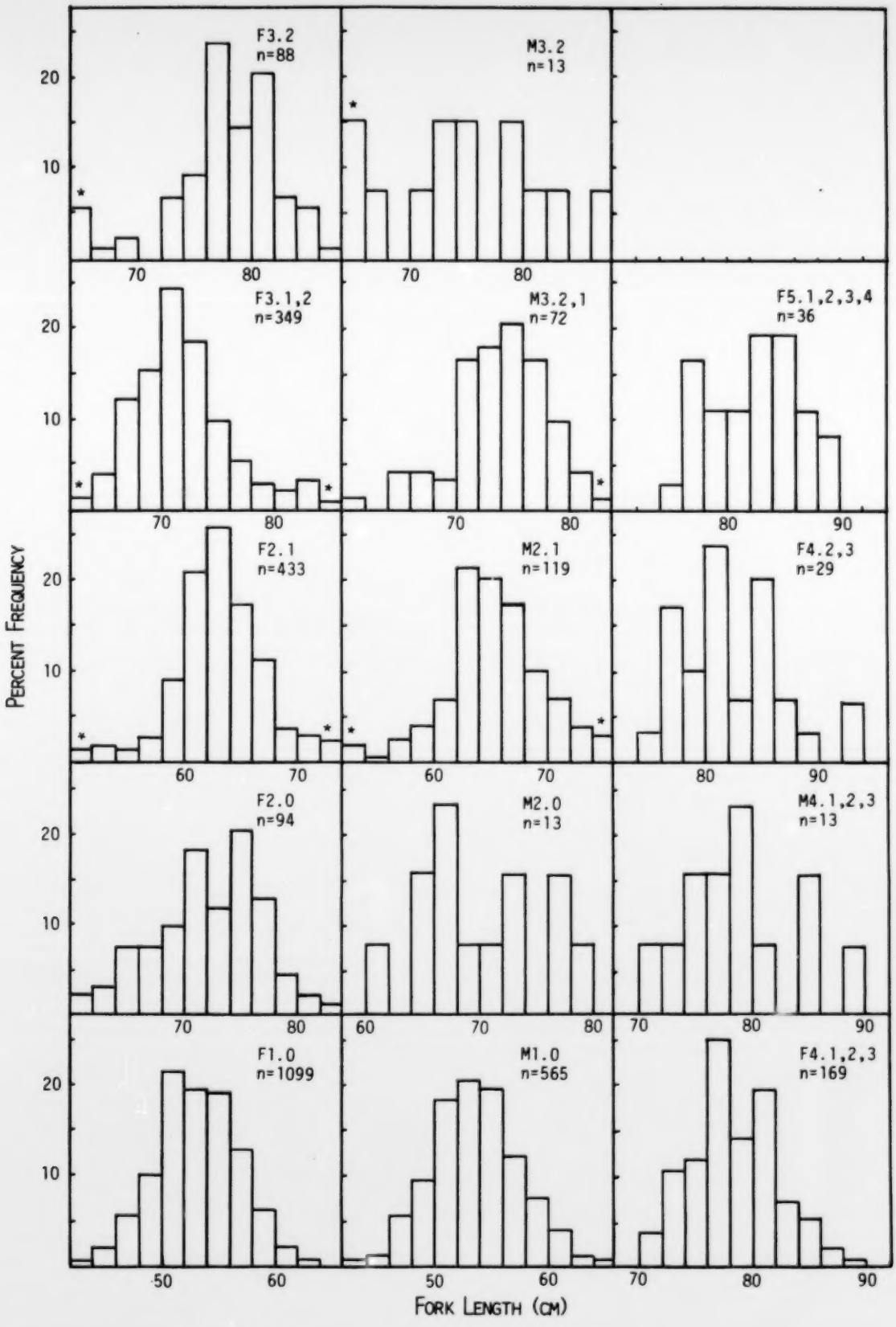

FIG. 5. Length-frequency distributions, by sex, age and spawning frequency, of Atlantic salmon from the Big Salmon River.

(X^2_1 = 1,361.1; P<0.001) data. Thus, pooling overall years of the data on salmon:grilse proportions is inadvisable. Within years, in six of nine years, the proportions of salmon and grilse in the angling catch differ significantly (P<0.01) from the fence count, but the differences are not systematic. Similar relationships occur when the proportions of large salmon and grilse are compared with estimated total returns to the river (Table 6).

Angling catch annually averaged about 24 percent of the total return between 1965 and 1973 (Table 5), whereas it averaged 15 percent of the fishway count between 1954 and 1962 and 23 percent of the fence count between 1964 and 1973 (Table 7). Angling catch was marginally significantly correlated with total return to the river (n = 9, r = 0.70, P<0.05).

As the summer progressed, the length of 1-SW salmon tended to increase, sometimes significantly, averaging 1.7 cm over a 3-month period, whereas weights decreased by 0.13 kg (Table 8). The sex composition of the run varied little between months, with perhaps a slight tendency for the proportion of females to increase in later months (Table 9).

Fish size and annual growth increment were related to sea-age, spawning history and sex. With few exceptions, lengths and weights of both sexes of Atlantic salmon maturing first after one-sea-winter varied greatly between years for age-groups less than three-sea-winters for males and four-sea-winters for females (Appendices A and B). Within a year, 1-SW males typically averaged longer than 1-SW females but were usually of similar weight (Table 10; Appendices C and D). Averaged over all years, male 1-SW salmon were longer than females (53.5 cm vs. 52.2 cm; P<0.001) and slightly heavier in weight (1.73 kg vs. 1.69 kg; P<0.05). Male and female, virgin, 2-SW salmon did not differ in length within years but differences in length occurred between years for each sex (Table 11; Appendices E and F). Male virgin 2-SW salmon were lighter (P<0.02) than female salmon. Weights of each sex did not differ within or between years. Over all years, male and female, virgin, 2-SW salmon averaged 68.9 cm and 71.0 cm long and weighed 3.07 kg and 3.91 kg, respectively.

Spawning history had less influence on the length and weight at age attained by males than by females, although females typically outlived males and reached larger mean final sizes (Tables 12 and 13; Fig. 6). After two sea-winters, 1-SW previous-spawning males were about 9 percent smaller than 2-SW virgin fish and reached, after three sea-years, lengths and weights approximating those of fish spawning first after two sea-winters. Previous-spawning 1-SW females spawning for the second consecutive time were about 11 percent smaller than 2-SW virgin fish and took four sea-years to attain lengths similar to 2-SW virgin fish and five sea-years to reach similar weights. Annual growth increments for length and weight declined between the first and second sea-years, with one exception - male, previous-spawning grilse which had similar weight gains during the first two sea-years. Three-sea-winter virgin salmon were recorded in only one year (1968) and were too few for detailed analysis.

Weight-length relationships were similar for salmon of each sex; age at first spawning and sex influenced only the adjusted means, with spawners of 2-sea-winter origin averaging longer than fish of 1-sea-winter origin and females averaging longer than males (Appendices G and H). A common weight-length relationship satisfactorily describes fish of each sex and all ages. The G.M. relationship found was $Y = -4.7055 + 2.8637\ X$, where $Y = \log_{10}$ weight (kg), $X = \log_{10}$ fork length (cm), n = 1,324, $r^2 = 0.932$ and $s^2_{(y.x)} = 0.0031$.

Within years, the lengths of 1-SW salmon collected at the counting fence were generally smaller, but non-significantly so (P>0.05), than those of angled fish; but when all years were combined, the weighted mean length of fish taken at the counting fence was longer than that of angled fish (Table 14). Conversely, when unweighted mean lengths were compared, angled fish were longer than fence-caught fish, but not significantly so (P>0.50). Lengths of angled, multi-sea-winter (M-SW) salmon were, in most years, non-significantly (P>0.05) longer than the lengths of fish collected at the counting fence. Averaged over all years, there was no significant difference (P>0.50) between the mean lengths (weighted or unweighted) of multi-sea-winter salmon taken at the counting fence or by angling.

Another way of examining these data is by two-way ANOVA. The method weights according to the variance of each mean and results in the conclusion that 1-SW fish taken at the counting fence averaged longer than angled fish and that mean lengths differed between years (Appendix I). Multi-sea-winter fish caught at the fence or angled were similar in length within a year but did differ in length between years. A catch method x year interaction effect occurred for M-SW fish. High heterogeneity of variance of lengths between 1-SW and M-SW fish preclude the use of another factorial model.

Age and length at smoltification influenced the length obtained by returning 1-SW salmon. Thus, age-3 smolts, which were on average longer than age-2 smolts when considered over several years ($F_{1,2611}$ = 432.4; P<0.001; Table 15), if not always within a year (Jessop 1975), produced 1-SW salmon that were slightly but significantly ($F_{1,999}$ = 16.2; P<0.001) longer than those of age-2 smolt

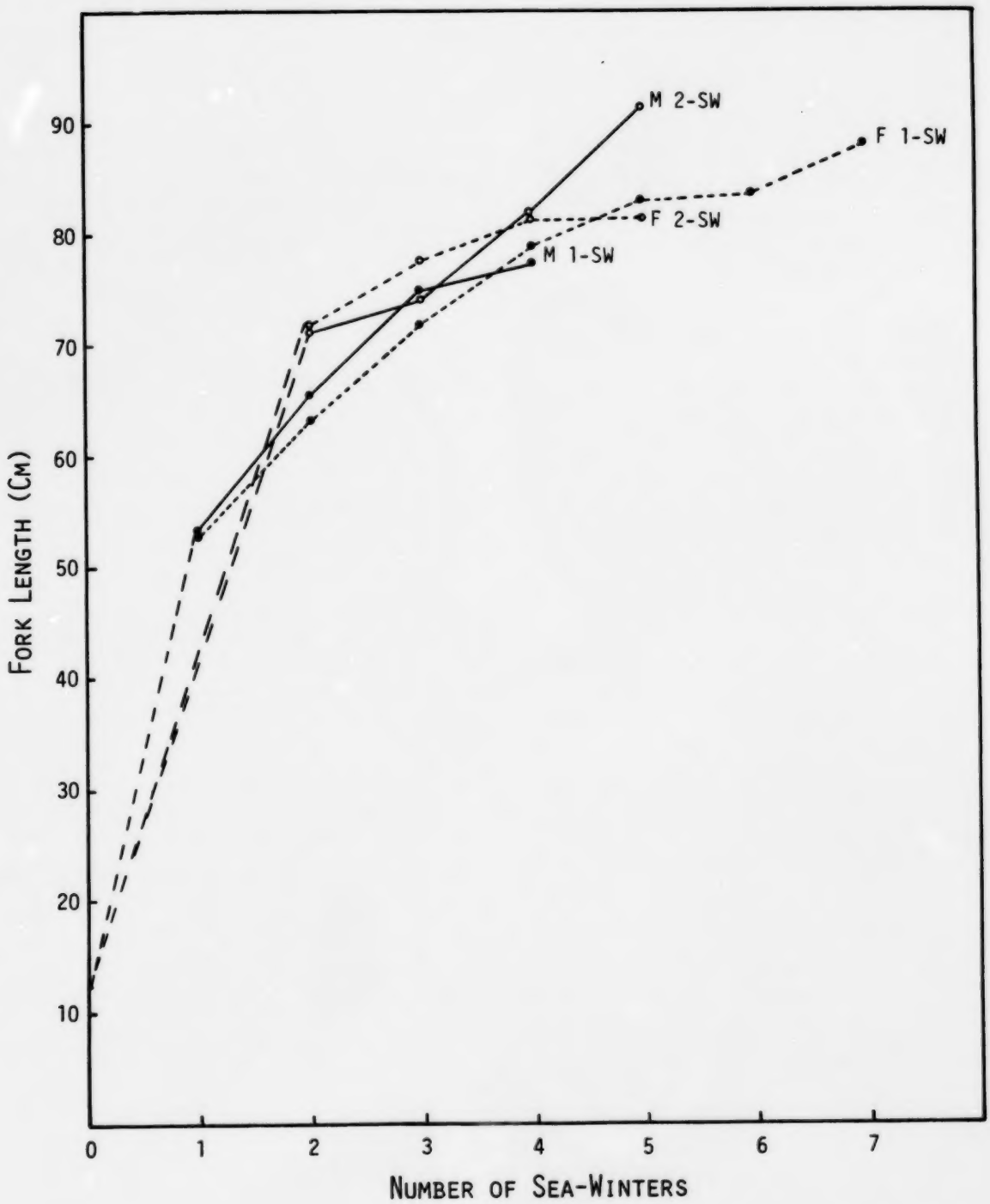

FIG. 6. Growth curves, by sex and sea-age at first spawning, of Atlantic salmon from the Big Salmon River.

origin. Growth increments during the first year at sea were similar ($F_{1,18}$ = 0.002; P>0.75) for salmon with origins as 2- and 3-year smolts.

The lengths of 2-SW salmon originating as age-2 smolts differed between years ($F_{3,45}$ = 3.75; P<0.025) but did not differ for fish originating as age-3 smolts ($F_{2,35}$ = 0.60; P>0.50; Table 16). However, age of smoltification made little difference to the length of 2-SWV (V = virgin) salmon returning to the river either within a year or when data for several years were averaged ($F_{1,44}$ = 0.69; P>0.25). Growth increments also were similar ($F_{1,9}$ = 0.25; P>0.50) for 2-SWV salmon of different smolt age. During the second year at sea, the growth increment averaged 17 cm, or less than half of the 38-cm growth increment during the first year at sea.

No consistent relationship was found between the age composition of the smolt run and the age at smoltification of returning 1- and 2-SW virgin salmon. The mean age at smoltification varied between years for smolts and 1-SW salmon but not for 2-SW salmon (Table 17). In most years, the age at smoltification of 1-SW salmon differed from the age composition of the smolt run, whereas the age at smoltification of 2-SW salmon did not. The age at smoltification was similar in most years for 1- and 2-SW salmon.

Survival rates from smolt to grilse varied greatly between years but little difference was noted in the average (6-year) smolt-to-grilse survival rate of grilse smoltifying at age-2 (x = 4.2 percent), age-3 (4.8 percent) or age-4 (4.1 percent)(Table 18). The instantaneous mortality (Z) averaged 3.2 and fluctuated between years. Survival from smolt to grilse averaged 4.2 percent for untagged smolts and 0.3 percent for tagged smolts, a 14-fold difference (Table 19).

Adult survival rates (s) varied with sex and age at maturation. Mean annual marine survival rates (maximum likelihood estimate ±95 percent CI; Robson and Chapman 1961) for salmon of all ages which first spawned after one sea-winter were higher for females (s = 0.48 ± 0.02) than for males (s = 0.34 ± 0.03) but were similar for males and females which first spawned after two sea-winters (s= 0.41 ± 0.13 for males; s = 0.39 ± 0.02 for females, based on numbers of fish in Table 12).

Female 1-SW salmon returning to the counting fence outnumbered males by almost 2:1, although the ratio fluctuated between years (Table 20). The proportion of salmon and grilse differed between years (X^2_7 = 21.8; P<0.01). Most of the between-years heterogeneity derives from the two years with small sample sizes, 1967 and 1969. Their exclusion results in marginally significant heterogeneity (X^2_5 = 12.2; P<0.05). Within a year, there was no seasonal trend in the proportions of 1-SW salmon of each sex arriving at the fence. The sex ratio of all age-classes of salmon recorded from the angling catch slightly but non-significantly (X^2_1 = 0.87; P>0.10) underestimated that recorded at the counting fence (Table 21). Between-years heterogeneity in sex ratios was non-significant for fish captured both at the counting fence (X^2_7 = 6.2; P>0.50) and by anglers (X^2_5 = 4.1; P>0.50).

Within-river recaptures of native Atlantic salmon tagged and released as smolts between 1967 and 1971 varied considerably between years (Table 22). The rate of recapture declined sharply as the years after release increased, with the first year recovery rate averaging only 0.3 percent for fish tagged as smolts and 6.3 percent for fish tagged after one sea-winter. In 1971, 71 adult salmon were also tagged in a drift-netting operation about 1-2 km off the mouth of the river. Twenty-eight fish were recaptured at the counting fence in 1971. Five of these were again recaptured in 1972.

Although many recaptures occurred in successive years, problems such as washouts or overflowing of the counting fence resulted in discontinuities in the record. However, at least seven fish were tagged as smolts and recovered in the river in each of two consecutive years, while of three fish tagged as adults, two were recovered in two successive years and one fish was recovered in three consecutive years. One interesting case is that of fish B11290, which was tagged as a 2-year-old smolt in 1967 and subsequently recovered annually between 1970 and 1973. In 1970, it was recorded as a female, 1-sea-winter previous spawner with two consecutive spawnings, and in each following year, one additional spawning mark was identified. At release, the fish was 15.2 cm long and on subsequent recoveries was 76 cm, 82 cm and 91 cm long, weighing respectively 4.8 kg, 6.2 kg, and 8.2 kg. The ageing of most recaptured salmon was consistent with the tagging record but three fish were anomalous in that they showed one less spawning mark on second recapture than on the first recapture. Each of these fish had been tagged as an adult salmon and had previously spawned at least three times according to their scale records.

No relationship was found between smolt year-class abundance and egg deposition within the range of data available. Survival from egg to smolt at egg depositions of 16.5-31.4 eggs m^{-2} of rearing area varied between 0.14 and 0.21 percent (Table 23). Egg depositions per m^2 of spawning area were estimated to be about 30 times higher than per m^2 of rearing habitat. Smolt yield.100 m^{-2} of rearing habitat averaged 4.59 (range 2.55-5.81).

DISCUSSION

The late-summer timing of the Atlantic salmon run to the Big Salmon River is typical of the small- to medium-size streams in the lower and middle portions of the Bay of Fundy. Most salmon arrive between mid-August and mid-September, whereas in the upper Bay of Fundy (Chignecto and Minas basins), salmon arrival peaks several weeks later (White and Huntsman 1938). Both genetic and environmental factors are known to influence seasonal patterns of adult return (Saunders 1967; Elson 1973).

The times of salmon entry vary between rivers, with factors such as discharge and water temperature influencing both river entrance and upstream migration rates (Banks 1969; Mills 1971). At the Big Salmon River counting fence, the observed daily salmon count varied with discharge level and the seasonal arrival of fish in a manner similar to that described by Allan (1965). Late runs are typical of small coastal streams which often have low summer water levels. The monthly return of similar proportions of large salmon and grilse is also consistent with the occurrence of a single major run of fish such as occurs in the smaller inner Bay of Fundy streams. The associated predominance of fish which first spawned after one winter at sea is typical of smaller rivers (Gardner 1976; Power 1981).

Although a counting fence may be one of the preferred methods for obtaining detailed information on the numbers, life history and population dynamics of migratory fish, the periodic occurrence of disabling floods and differences in program objectives and resources over time resulted in data that were sometimes incomplete or discontinuous. Such omissions are not expected to greatly affect any conclusions reached in this analysis.

However, the limited time span over which the data were collected is a more serious limit to their usefulness. Consequently, analyses requiring an extended data series, such as stock-recruitment relationships, could not be made.

The impact of commercial fisheries on this stock was probably minimal. Commercial exploitation appears to have been limited primarily to the weir fisheries of the Bay of Fundy, since few fish were caught by the driftnet fishery which existed off the mouth of the Saint John River or the interception fisheries of Atlantic coastal Nova Scotia, Newfoundland or Greenland (Jessop 1976). The small-scale drift-net fishery that operated near the Big Salmon River during the late 1960s ceased in 1970. A sizeable catch (1,700 fish) was recorded in 1968 but no record exists of catches in other years.

Little information is available on the life history and population dynamics of Atlantic salmon stocks which mature primarily after one sea-winter, but they might be expected to differ when compared with stocks maturing after two or more sea-winters, given the influence of genetics on growth rates at various life stages and on age and size at sexual maturity (Naevdal et al. 1976; Saunders 1981).

Wide fluctuations in the proportions of large salmon and grilse might be expected in stocks consisting essentially of previous, consecutive-spawning, 1-sea-winter fish but can also be found in other stocks (Dymond 1963; Allan 1965; Went 1970). Such fluctuations in Big Salmon River-type stocks probably reflect the variability in annual smolt production and subsequent survival through repeated spawnings. Variability between different salmon stocks in annual maturation as 1- or 2-sea-winter fish may result from differences in migratory patterns and responses to low, winter sea temperatures (Saunders et al. 1982). The large number of year-classes (often six or more) available for spawning undoubtedly reduces the impact of short-term periods of low reproduction success or failure. For example, in 1969, probably less than 10% of egg deposition was by virgin spawners; the balance was derived from previous spawners of several year-classes. The large salmon:grilse ratios of stocks having large components of previous spawners are not directly comparable with the ratios of stocks that do not; comparison of the proportions of virgin 1- and 2-sea-winter fish would be more appropriate.

Criteria based on weight or length are often used to distinguish between grilse and large salmon (Allan and Ritter 1977) but the potential errors of this method are not often quantified. Differences between scale-age and weight criteria averaged 10 percent but single-year differences of up to 22 percent occurred. Large errors in "salmon/grilse" classification by weight were also reported by Went (1970). Clearly, the use of scale-age is preferable in populations with high and variable proportions of previous spawners.

Increased angling catch rates after the mid-1960s probably resulted both because increasing returns of salmon drew more anglers and installation of the counting fence caused more attention to be paid to catch statistics.

Angling catches are occasionally treated as representative of total stock composition for the purpose of estimating life-history parameters (Schaffer and Elson 1975). The higher the rate of angling exploitation, the smaller the potential error generally expected in parameter estimates. With the annual exploitation rate averaging 24 percent at Big Salmon River between 1965 and 1973,

about 8 percent more grilse and correspondingly fewer large salmon were angled than would be expected from the composition of the fence count.

Kerswill (1971) also reported differential exploitation of large salmon and grilse in the Miramichi River, with the proportion of grilse caught exceeding that of large salmon by about 7 percent for data averaged over twelve years and with an angling exploitation rate of 26 percent of fish escaping the commercial fishery. However, given the significant heterogeneity in salmon:grilse proportions between years it may be inadvisable to average the data over several years (Steel and Torrie 1960). This deduction, combined with the often significant differences within years between angling and counting-fence salmon:grilse ratios (difference range -14 to 27 percent) and the non-systematic nature of these differences, leads to the conclusion that salmon:grilse ratios derived from angling catches may be unsuitable for use as representative of the true proportions in the run. Nonetheless, angling catches may provide reliable estimates of the sex composition of the run. A small portion of the differences between fence and angling origin estimates of run composition might be accounted for by the looser categorization standards for angled fish, since not all were weighed. Walters and Ludwig (1981) suggest that lack of an estimate of measurement error variance and the presence of measurement errors greater than + 30 percent or so render a data set useless, at least for stock and recruitment purposes.

Comparison of the lengths of angled 1-SW salmon with those taken at the counting fence reveals a case of Simpson's paradox, in which different conclusions are arrived at depending upon whether weighted or unweighted means are used to summarize a series of cross-classified data having large inequalities in subclass numbers (Snedecor and Cochran 1980; Chang 1983). The use of weighted means produces conclusions similar to that of a two-way ANOVA. Thus, angling catches using relatively small sample sizes may provide reliable estimates of size composition of M-SW fish but not of 1-SW fish. Within-year results may also differ from those based on several years of data. Sample, variance and data series size clearly influence the sensitivity with which differences are detected and the reliability of conclusions drawn from the analysis.

In summary, angling catches were found to provide useful estimates of sex composition of the run but not necessarily of the size composition or proportions of salmon and grilse.

The increasing length, as the summer progressed, of 1-SW salmon arriving at the counting fence probably resulted from the longer period of marine feeding and growth of later arrivals. The associated decline in weight likely results from the cessation of active feeding following approach and entrance of the river, coupled with any delays to upstream migration due to summer low-water levels. Hoar (1939) reported a decrease in the number of feeding Saint John River salmon during early July and an associated decrease in condition factor. Female 1-SW virgin salmon evidently have higher condition factors than do males, as deduced from their shorter mean lengths but similar mean weights. This is consistent with their greater gonadal development. During the second year at sea, virgin salmon of both sexes experienced decreasing growth rates, attaining growth increments less than half that of the first year. Growth patterns also changed and female 2-SW virgin salmon became similar in length but heavier than males as the differences in gonadal development between the sexes increased. Nonetheless, the variability of weight and length data with age and sex is such that a common weight-length relationship is appropriate when considering information from several years.

Growth rates in length and weight declined progressively with age and frequency of spawning. Of salmon with equal sea-ages, those with more spawnings were of smaller size and had slower average growth rates than had salmon with fewer spawnings. These differences disappeared after 3-5 sea-winters, depending upon the sex. Allen et al. (1972) reported a progressive decline in growth rate with increasing age for salmon from a variety of origins.

Females grew slower after repeated spawning than did males, yet attained larger final size because they lived longer. This pattern is consistent with the greater energy expenditure of females for reproduction (Belding 1934) and their typically longer life span (Dymond 1963).

Stocks consisting essentially of previous, consecutive-spawning, 1-sea-winter salmon make a contribution to the confusion regarding the relationship between age at smoltification and sea-age upon return to the river (Gardner 1976; Chadwick et al. 1978). When, as occurs in the Big Salmon River, about 94 percent of all virgin spawners return after one sea-winter, and when there are only two important smolt age-groups, the hypothesis that older smolts tend to return after a shorter sea absence (Hutton 1937) is unsupported as is the conclusion that younger smolts are destined to return after one sea-winter (Dahl 1937). For the Big Salmon River, no difference was found between virgin 1- and 2-SW salmon in mean age at smoltification. Chadwick et al. (1978) suggest that the younger, faster growing smolts from Western Arm Brook become grilse; in fact, they merely show that all smolts become grilse because the spawning stock consists entirely of grilse.

The contention (Shearer 1973) that the larger smolts from a year-class become grilse while the smaller become salmon is also unsupported by Big Salmon River data. Age-4 smolts, which were longer than smolts of other age-groups, produced few grilse, while the smallest smolts, at age-2, produced more grilse than would be expected from the age composition of the smolt run. The mid-sized, age-3 smolts produced more 2-SW virgin salmon than expected either from the smolt composition or Shearer's hypothesis. Comparisons of specific life-history parameters are probably best made within stock groupings having similar life-history characteristics. Gardner (1976) concludes that "there is no over-riding [sic] causal relationship between the growth (river or sea) and the time of return to fresh water" and that no systematic differences occur in the growth of different age-classes during their first sea winter.

Length differences between age-2 and -3 smolts persisted through one but not two sea-winters. Thus, the shorter, age-2 smolts produced shorter 1-SW virgin salmon than did age-3 smolts although they had similar marine growth increments. Chadwick et al. (1978) reported comparable observations. The approximately equal lengths of 2-SW virgin salmon of both smolt-age origins indicates growth compensation during the second sea-winter or perhaps reflects a sampling artifact. The minimal commercial exploitation of this stock (Jessop 1976) reduces the influence of any differential selection of larger fish.

Substantial annual variability occurred in the relationship between age-composition of the smolt run and age at smoltification of returning adults. Over a period of years, the smolt age and sea age were not statistically independent, as was also reported by Thorne and Mitchell (1981), and thus this life-history characteristic is not a useful test of the parent stream theory. Gardner (1976) stressed that the freshwater age-composition of the adult stock does not necessarily reflect that of the emigrating smolt population.

Untagged fish were used to estimate smolt-to-grilse survival rates because tagged smolts experienced high mortality rates, both short-term (Jessop 1975) and long-term. Tagging of smolts later in the run, when smolt condition was declining, resulted in sharply higher short-term mortality. The 14-fold difference in the survival of untagged versus tagged smolts contrasts markedly with the 4-fold difference reported by Saunders and Allen (1967) for smolts from the Miramichi River. No estimates of tag loss were made but losses averaging 31 percent have been reported (Ritter, pers. comm.[1]). Such losses would raise the apparent survival rate of untagged fish and decrease it for tagged fish, thereby exaggerating the difference.

Bias associated with a counting fence that is less than 100% efficient (Jessop 1975), coupled with the difficulties inherent in annually estimating its efficiency and compensating for it, tends to produce overestimates of smolt-to-grilse survival, as does the passage of uncounted smolts due to flood conditions or the delayed installation of the counting fence. The two latter factors are of no concern except for 1966 when the counting fence was overtopped for one day during the middle of the run. No subtractions from the total count were made for smolts killed against the counting fence (mean, 4 percent of count; range, 2-6 percent), which tends to reduce survival rates. Annual differences in the time (start and duration) of smolt tagging will also have an effect, since smolts tagged later in the run have a higher tagging mortality (Jessop 1975). Considering all factors, Big Salmon River smolt-to-grilse survival rates are probably somewhat overestimated. The causes of variation in sea-survival of post-smolts are problematic; adverse climate and hydrographic conditions, particularly sea temperatures, are likely factors (Scarnecchia 1984).

Mean smolt-to-grilse survival rates were similar for fish of different smolt ages from the Big Salmon River but differed for salmon from Western Arm Brook, where the range of smolt ages and sizes was greater (Jessop 1975; Chadwick et al. 1978; Chadwick 1981). The lower smolt-to-grilse survival rates for Big Salmon River fish may relate to their smaller size when compared with smolts from Western Arm Brook; because survival, at least for tagged fish, tends to increase, up to a threshold size, with increased smolt size (Ritter 1977).

The tendency of adult females to live longer than males (Dymond 1963) follows from their higher annual survival rate and predominance in the population. Grilse-run rivers, such as the Big Salmon River, Apple River (White and Huntsman 1938), Western Arm Brook (Chadwick et al. 1978) and the Petitcodiac River (J.R. Semple, pers. comm.) tend to have predominately females, whereas in rivers where there exists a major component of virgin, multi-sea-winter fish, such as the Miramichi (Ruggles and Turner 1973) and Sand Hill rivers (Pratt et al. 1974), the grilse component is mostly male and the multi-sea-winter component is mostly female. Myers (1984) concluded that this is due to mortality associated with precocious maturation of males.

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1. Ritter, J.A. 1984. Biologist. Freshwater and Anadromous Division, Fisheries Research Branch, Dept. of Fisheries and Oceans, Halifax, Nova Scotia.

Salmon from the Big Salmon River displayed a moderately high degree of homing ability, as evidenced by the number of recaptures in successive years and absence of recaptures in other streams (Jessop 1976). Ducharme (1969) reported salmon from the Big Salmon River which returned for their fifth and sixth spawning trips. This study found additional fish which were returning for their sixth spawning and one which was returning for its seventh spawning. These fish may be even older and have completed more spawnings than their scales reveal because of the possibility that one or more annuli may be reabsorbed during the spawning migration, as was noted by White and Medcof (1968) and this study.

There exists an intriguing resemblance between Atlantic salmon from the Big Salmon River and other small Bay of Fundy rivers and sea-run brown trout (Salmo trutta) in the limited extent of their marine migrations, their maturation predominately as grilse and their high incidence of multiple spawnings. Local tradition attributed the "unusual" life history of Big Salmon River fish to the introduction of brown trout x Atlantic salmon hybrids reputedly developed by Mr. J. Catt at the Saint John hatchery of the Department of Fisheries during the late 1920s and 1930s. However, the hatchery stocking records (Annual Report, Dept. of Marine and Fisheries, 1924-29; Dept. of Fisheries, 1930-65) make no mention of any such releases into the Big Salmon River, nor does Catt (1950) when he discusses brown trout introductions in New Brunswick and Nova Scotia. There is no evidence of brown trout or their hybrids being introduced into the Big Salmon River. It is therefore not surprising that Beland (1979) found no evidence of brown trout genes in the population and that Roberts (pers. comm. referred to in Saunders [1981]) determined that Big Salmon River fish have chromosome numbers characteristic of Atlantic salmon.

The present Big Salmon River salmon population probably derives mainly from strays from other Bay of Fundy rivers. Following installation of the fishway during the early 1930s, salmon were reported using it in the years prior to the start of hatchery introductions in 1938 (letter file, Dept. of Fisheries, Halifax). The early introductions are believed to have derived mainly from salmon netted in or near the Saint John Harbor and could have included fish originating in the upper regions of the Bay of Fundy, although transfers to the Saint John hatchery of supplementary quantities of eggs of Miramichi River origin began in 1939. Since the survivors of introduced stocks may assume the characteristics of the native stock (White and Huntsman 1938; Jessop 1976) there is no way of knowing what contribution these fish may have made to reestablishment of the Big Salmon River run. It may be small, however, because introductions during the 1960s of smolts of Miramichi River and Restigouche River orgin fared poorly relative to the native stock (Jessop 1975, 1976), as may have earlier non-native introductions, perhaps because of genetic maladaption to their new environment (Moller 1970). Such maladaption apparently increases with increasing distance and environmental differences between donor and recipient streams (Ritter 1975; Saunders 1981).

No relationship was found between egg deposition and smolt year-class strength for the stock of Atlantic salmon in the Big Salmon River, probably because of the limited number of years (4) and range of data values. Poaching of salmon and angling catches unaccounted for by the creel survey are believed to have been minor and should have little effect on the estimates of egg deposition. Egg-to-smolt survival rates in the Big Salmon River were about 10 percent of those reported by Chadwick (1982). Contrary to Chadwick's assertion that freshwater survival of salmon is similar on very different watersheds, survival clearly may be very different, varying between locations and years on the basis of numerous environmental factors (Symons 1979) and perhaps on the density of egg deposition (Buck and Hay 1984).

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TABLE 1. Monthly counts of Atlantic salmon at the Big Salmon River counting fence and estimated total river return and escapement, 1964-73.

Month	Numbers of fish[1]										Mean % of annual total[2]
	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	
Salmon counts at fence											
May	0	0	3	0	0	0	0	0	1	0	0.0
Jun	1	12	82	24	13	7	30	0	5	10	0.9
Jul	441	84	135	69	142	304(few)	316	132	270	24	9.5
Aug	669	2,068	861	1,798	402	119	420	330	471	72(575)	35.5
Sep	801	847	3,277	613	974	452	437	178	552	98	40.6
Oct	48	483	272	1(1,100)	987	374	101(few)	38(200)	61	14	11.9
Nov	1	2	6	0	13	18	2	0	0	0(120)	0.2
Fence totals	1,961	3,496	4,636	2,505	2,531	1,274	1,308	678	1,360	218	
Angled downstream[3]	NA	NA	586	584	NA	NA	297	197	155	254	
Minimum total river return	1,961	3,496	5,222	3,089(4,189)	2,531	1,274	1,605	875(1,075)	1,515	472(1,167)	
Angled upstream[3]	NA	NA	189	495	NA	NA	194	73	169	242	
Escapement	1,961	3,496	4,447	2,010(3,110)	2,531	1,274	1,114	605(805)	1,191	- (671)	

1. Data in parentheses are estimated numbers of fish bypassing the counting fence during high-water periods.

2. Excludes years with data in parentheses.

3. NA indicates data not available.

TABLE 2. Monthly totals of large and grilse Atlantic salmon at the Big Salmon River counting fence, 1964-73.

Year		Numbers of fish and percentages[1]							
		May	Jun	Jul	Aug	Sep	Oct	Nov	Totals
1964	Large salmon								
	Number	0	1	340	303	603	29	0	1,276
	Percent	0.0	0.1	17.3	15.5	30.7	1.5	0.0	65.1
	Grilse								
	Number	0	0	101	366	198	19	1	685
	Percent	0.0	0.0	5.2	18.7	10.1	1.0	0.1	34.9
1965	Large salmon								
	Number	0	1	55	898	395	198	1	1,548
	Percent	0.0	0.0	1.6	25.7	11.3	5.7	0.0	44.3
	Grilse								
	Number	0	11	29	1,170	452	285	1	1,948
	Percent	0.0	0.3	0.8	33.5	12.9	8.2	0.0	55.7
1966	Large salmon								
	Number	3	14	49	324	1,683	94	4	2,171
	Percent	0.1	0.3	1.1	7.0	36.3	2.0	0.1	46.8
	Grilse								
	Number	0	68	86	537	1,594	178	2	2,465
	Percent	0.0	1.5	1.9	11.6	33.4	3.8	0.0	53.2
1967	Large salmon								
	Number	0	21	47	1,288	369	1	-	1,726
	Percent	0.0	0.8	1.9	51.4	14.7	0.0	-	68.9
	Grilse								
	Number	0	3	22	510	244	0	-	779
	Percent	0.0	0.1	0.9	20.4	9.7	0.0	-	31.1
1968	Large salmon								
	Number	0	13	63	214	426	569	3	1,288
	Percent	0.0	0.5	2.5	8.5	16.8	22.5	0.1	50.9
	Grilse								
	Number	0	0	79	188	548	418	10	1,243
	Percent	0.0	0.0	3.1	7.4	21.7	16.5	0.4	49.1
1969	Large Salmon								
	Number	0	7	273	108	389	296	13	1,086
	Percent	0.0	0.5	21.4	8.5	30.5	23.2	1.0	85.2
	Grilse								
	Number	0	0	31	11	63	78	5	188
	Percent	0.0	0.0	2.4	0.9	4.9	6.1	0.4	14.8
1970	Large salmon								
	Number	0	23	185	310	287	72	1	878
	Percent	0.0	1.8	14.1	23.7	21.9	5.5	0.1	67.1
	Grilse								
	Number	0	9	131	110	150	29	1	430
	Percent	0.0	0.7	10.0	8.4	11.5	2.2	0.1	32.9
1971	Large salmon								
	Number	0	0	67	156	69	12	-	304
	Percent	0.0	0.0	9.9	23.0	10.2	1.8	-	44.8
	Grilse								
	Number	0	0	65	171	112	26	-	374
	Percent	0.0	0.0	9.6	25.2	16.5	3.8	-	55.2
1972	Large salmon								
	Number	1	1	66	125	203	31	-	427
	Percent	0.1	0.1	4.9	9.2	14.9	2.3	-	31.4
	Grilse								
	Number	0	4	204	346	349	30	-	933
	Percent	0.0	0.3	15.0	25.4	25.7	2.2	-	68.6
1973	Large salmon								
	Number	0	8	12	22	38	7	-	87
	Percent	0.0	3.7	5.5	10.1	17.4	3.2	-	39.9
	Grilse								
	Number	0	2	12	50	60	7	-	131
	Percent	0.0	0.9	5.5	22.9	27.5	3.2	-	60.1
Mean(%)									
	Large salmon	0.0	0.8	8.0	18.3	20.5	6.8	0.2	54.0
	Grilse	0.0	0.4	5.4	17.4	17.4	4.7	0.2	46.0
Range(%)									
	Large salmon	0.0-0.1	0.0-3.7	1.1-21.4	7.0-51.4	10.2-36.3	0.0-23.2	0.0-1.0	
	Grilse	0.0-0.0	0.0-1.5	0.9-33.5	0.9-33.5	4.9-33.4	0.0-16.5	0.0-0.4	

1. Percentages of annual grand totals.

TABLE 3. Smolt/adult age composition of Atlantic salmon returning to the Big Salmon River counting fence, 1964-73.

Age Smolt. adult	Numbers of fish and percentages																				Grand mean%	% composition by smolt age
	1964		1965		1966		1967		1968		1969		1970		1971		1972		1973			
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%		
2.1	4	7.4	27	24.8	69	40.1	9	5.4	187	20.2	4	1.1	128	20.5	146	45.9	207	49.4	1	0.5	23.5	
2.2	9	16.7	5	4.6	28	16.3	32	19.2	136	14.7	73	20.3	30	4.8	20	6.3	9	2.1	1	0.5	10.3	
2.3	5	9.3	8	7.3	3	1.7	22	13.2	64	6.9	26	7.2	149	23.8	19	6.0	0	0.0	0	0.0	8.9	
2.4	0	0.0	3	2.8	0	0.0	2	1.2	21	2.3	13	3.6	37	5.9	41	12.9	0	0.0	0	0.0	3.5	
2.5	0	0.0	1	0.9	0	0.0	2	1.2	8	0.9	1	0.3	12	1.9	6	1.9	0	0.0	0	0.0	0.9	
2.6	0	0.0	0	0.0	0	0.0	1	0.6	0	0.0	2	0.6	1	0.2	1	0.3	0	0.0	0	0.0	0.2	
2.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	0	0.0	0	0.0	0	0.0	0.0	47.2
3.1	19	35.2	44	40.4	51	29.7	22	13.2	247	26.6	7	1.9	126	20.2	50	15.7	172	41.1	124	67.8	25.9	
3.2	9	16.7	5	4.6	17	9.9	32	19.2	165	17.8	158	44.0	15	2.4	9	2.8	21	5.0	48	26.2	14.4	
3.3	5	9.3	7	6.4	3	1.7	34	20.4	66	7.1	54	15.0	105	16.8	9	2.8	3	0.7	7	3.8	8.8	
3.4	1	1.9	6	5.5	1	0.6	3	1.8	20	2.2	13	3.6	18	2.9	14	4.4	6	1.4	0	0.0	2.5	
3.5	0	0.0	2	1.8	0	0.0	4	2.4	4	0.4	2	0.6	2	0.3	2	0.6	1	0.2	0	0.0	0.5	
3.6	0	0.0	0	0.0	0	0.0	0	0.0	2	0.2	0	0.0	0	0.0	0	0.0	0	0.0	2	1.1	0.1	52.1
4.1	1	1.9	0	0.0	0	0.0	3	1.8	5	0.5	3	0.8	1	0.2	0	0.0	0	0.0	0	0.0	0.4	
4.2	1	1.9	0	0.0	0	0.0	1	0.6	2	0.2	2	0.6	0	0.0	0	0.0	0	0.0	0	0.0	0.2	
4.3	0	0.0	1	0.9	0	0.0	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0.1	
4.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3	0	0.0	0	0.0	0.1	0.7
Totals [1]	54		109		172		167		927		359		625		318		419		183			
1-SW [2,3]	24	44.4	71	65.1	120	69.8	34	20.4	439	47.4	14	3.9	255	40.8	196	61.6	379	90.5	125	68.3		
2-SW	19	35.2	10	9.2	45	26.2	65	38.9	303	32.7	233	64.9	45	7.2	29	9.1	30	7.2	49	26.8		
Multi-SW	11	20.4	28	25.7	7	4.0	68	40.7	185	19.9	112	31.2	325	52.0	93	29.3	10	2.3	9	4.9		

1. Total fish aged during the 10 years of sampling was 3,333.

2. SW = sea-winter, virgin.

3. Ten 3-SW fish caught in 1968 are excluded.

TABLE 4. Comparison of the percentages of the annual total return of Atlantic salmon consisting of 1-sea-winter fish, as determined by scale ages, and of grilse, as estimated by weight, Big Salmon River, 1964-73.

Year	Percentage of 1-SW fish (scale aged)	Percentage of grilse (est. by weight)	Difference in percentage
1964	44.5	34.9	9.6
1965	65.2	55.7	9.5
1966	69.8	53.2	16.6
1967	20.4	31.1	-10.7
1968	47.3	49.1	-1.8
1969	3.8	14.8	-11.0
1970	40.9	32.9	8.0
1971	61.6	55.2	6.4
1972	90.5	68.6	21.9
1973	68.3	60.1	8.2

TABLE 5. Comparison of the annual angling catch of grilse and large Atlantic salmon with the fence count, Big Salmon River, 1965-73.

	Angling catch[1]			Fence count			
Year	n	% large salmon	% grilse	n	% large salmon	% grilse	Difference in percentage, fence vs. angling
1965	521	58	42	3,496	44	56	-14
1966	775	28	72	4,634	47	53	19
1967	1,119	42	58	2,505	69	31	27
1968	291	53	47	2,531	51	49	-2
1969	529	82	18	1,274	85	15	3
1970	491(125)	53(64)	47(36)	1,308	67	33	14(3)
1971	266(24)	31(33)	69(67)	678	45	55	14(12)
1972	324(59)	34(35)	66(65)	1,360	31	69	-3(-4)
1973	496(86)	25(36)	75(64)	213	41	59	16(5)
Mean		45.1	54.9		53.3	46.7	8.2
Range		25-82	18-75		31-85	15-69	-14 to 27

1. Data in parentheses represent angling catches upstream of counting fence.

TABLE 6. Comparison of the annual angling catch with the total return of grilse and large Atlantic salmon to the Big Salmon River, 1964-73.

Year	Angling catch [1]				Total return [2]				Angling catch as % of total return
	Large salmon		Grilse		Large salmon		Grilse		
	n	%	n	%	n	%	n	%	
1964	56 [3,4,6]	-	93	-	1,306	64	743	36	7
1965	303 [3,4]	58	218	42	1,727	45	2,076	56	14
1966	217 [3]	28	558	72	2,374	45	2,850	56	15
1967	474	42	645	58	2,624 [5]	64	1,465	36	27
1968	154 [4]	53	137	47	1,379	51	1,324	49	11
1969	436 [3]	82	93	18	1,207	74	423	26	32
1970	260	53	231	47	1,013	63	592	37	31
1971	82	31	184	69	362	42	510	59	31
1972	109	34	215	66	477	32	1,038	68	21
1973	126	25	370	75	372 [7]	41	538	59	55
Mean		45.1		54.9		52.1		48.2	24.4
Range		25-82		18-75		32-74		26-68	7-55

1. Angling catch = catch upstream and downstream of counting fence.

2. Total return = fence count + angling catch downstream of fence.

3. Proportion of salmon and grilse angled downriver of fence based on 5-yr mean of 34% salmon, 66% grilse.

4. Proportion of fish caught upstream and downstream of fence based on 6-yr mean of 59% of fish angled downstream.

5. Includes an estimated 1,000 fish that moved upriver during late Sept-Oct floods, divided according to previous salmon:grilse ratio.

6. Proportion of fish angled upriver of fence that were salmon and grilse based on 5-yr mean of 43% salmon, 57% grilse.

7. Includes estimates of fish moving upriver during flood periods and total return occurring downriver of fence prior to fence removal and which are assigned as salmon or grilse according to proportions in fence count.

TABLE 7. Comparison of the annual angling catch of Atlantic salmon with the fishway count (to 1962) and fence count, Big Salmon River, 1954-73.

Year	Count	Angling catch	Angling catch as % of count
1954	250	14	6
1955	95	6	6
1956	172	76	44
1957	1,682	270	16
1958	1,010	161	16
1959	341	44	13
1960	1,551	238	15
1961	706	53	8
1962	1,767	293	17
Mean (1954-62)			15.2
1963	-[1]	421	-[1]
1964	1,961	150	8
1965	3,496	521	15
1966	4,634	775	17
1967	2,505	1,119	45
1968	2,531	291	11
1969	1,274	529	42
1970	1,308	491	38
1971	678	266	39
1972	1,360	324	24
1973	213	496	-[2]
Mean (1963-73)			22.6

1. No count available; fishway removed.

2. Omitted due to inaccurate fence count caused by flooding.

TABLE 8. Fork lengths and weights, by month, of 1-sea-winter Atlantic salmon (sexes combined) from the Big Salmon River, 1964-73.[1]

		Lengths (cm)			Weights (kg)		
Year	Month	n	$\bar{X}$[1]	SD	n	$\bar{X}$[1]	SD
1964	Aug	24	54.0	2.80	-	-	-
	Totals	24	54.0	2.80	-	-	-
1965	Aug	30	57.4	3.24	-	-	-
	Sep	34	58.3	3.31	-	-	-
	Oct	5	60.5	3.31	-	-	-
	Totals	69	58.1	3.33	-	-	-
1966	Jun	5	52.8	3.77	-	-	-
	Jul	11	53.6	3.49	-	-	-
	Aug	55	53.8	3.22	-	-	-
	Sep	48	55.0	3.11	-	-	-
	Totals	119	54.3	3.25	-	-	-
1967	Aug	16	56.4	6.37	-	-	-
	Sep	18	55.7	3.08	-	-	-
	Totals	34	56.0	4.84	-	-	-
1968	Jul	37	51.4	3.38	3	1.40	0.0
	Aug	35	52.3	2.49	13	1.61	0.405
	Sep	317	52.7	2.80	317	1.68	0.239
	Oct	58	53.0	2.62	58	1.58	0.233
	Totals	447	52.6	2.83	403[2]	1.66	0.246
1969	Jul	1	45.0	-	1	1.59	-
	Aug	3	56.7	6.03	4	1.96	0.284
	Sep	5	50.6	3.44	5	1.54	0.327
	Oct	4	51.8	3.86	4	1.33	0.194
	Totals	13	51.9	4.91	14	1.60	0.350
1970	Jun	7	48.7	5.47	7	1.80	0.396
	Jul	95	48.4	3.02	95	1.42	0.341
	Aug	68	49.7	3.35	68	1.41	0.316
	Sep	60	50.5	3.25	60	1.36	0.300
	Totals	264[2]	49.4	3.30	264[2]	1.39	0.327
1971	Jul	58	51.5	2.51	58	1.69	0.284
	Aug	102	52.2	3.59	102	1.64	0.335
	Sep	64	53.2	2.89	64	1.62	0.260
	Oct	9	53.1	1.45	9	1.48	0.179
	Totals	233	52.3	3.15	233	1.64	0.300
1972	May	1	56.0	-	1	2.40	-
	Jun	2	53.0	-	2	1.90	-
	Jul	116	54.4	3.06	116	2.13	0.326
	Aug	166	55.2	3.19	166	2.15	0.334
	Sep	203	55.9	3.33	203	2.07	0.311
	Oct	7	57.3	4.35	7	1.93	0.550
	Totals	495	55.3	3.32	495	2.11	0.328
1973	Jun	3	50.7	3.51	3	1.90	0.346
	Jul	9	51.2	3.11	9	1.88	0.277
	Aug	37	51.2	3.32	37	1.59	0.301
	Sep	42	51.5	2.45	42	1.48	0.211
	Oct	2	50.0	-	2	1.30	-
	Totals	93	51.3	2.86	93	1.57	0.288

1. SNK-LSR used for multiple comparisons among means; solid lines indicate significant ($P < 0.05$) differences. Only means with $n \geq 5$ were tested.

2. Totals include fish for other months.

TABLE 9. Monthly sex composition of 1-sea-winter Atlantic salmon observed at the counting fence, Big Salmon River, 1968-73.[1]

	1968		1970		1971		1972		1973	
Month	n	% female	n	% female	n	% female	n	% female	n	% female
Jul	37	76	95	58	58	76	116	69	8	75
Aug	35	67	68	54	102	62	164	66	36	81
Sep	317	62	60	62	63	63	201	77	42	55
Oct	58	67	33	61	9	67	7	71	2	100
Mean		64		58		66		71		68

1. Data for 1969 not included because of low numbers of 1-sea-winter fish.

TABLE 10. Fork lengths and weights of male and female, 1-sea-winter Atlantic salmon from the Big Salmon River, 1965-73.

	Male						Female						Probability of difference	
	Length (cm)			Weight (kg)			Length (cm)			Weight (kg)				
Year	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	Length	Weight
1965	20	59.2	2.98	-[1]	-	-	49	57.6	3.38	-	-	-	< 0.05	-
66	-	-	-	-	-	-	-	-	-	-	-	-	-	-
67	17	56.3	3.38	-	-	-	17	55.7	6.06	-	-	-	> 0.50	-
68	163	53.2	3.39	148	1.68	0.265	298	52.2	3.05	255	1.65	0.235	< 0.01	> 0.50
69	9	53.6	4.90	9	1.65	0.377	4	48.3	2.50	5	1.52	0.317	> 0.05	< 0.02
1970	107	50.2	3.39	107	1.42	0.333	157	48.9	3.13	157	1.37	0.322	< 0.01	> 0.20
71	79	52.5	3.31	79	1.59	0.271	153	52.2	3.06	153	1.67	0.311	> 0.05	> 0.05
72	143	55.9	3.88	143	2.12	0.361	352	55.1	2.98	352	2.11	0.313	< 0.05	> 0.50
73	28	52.1	2.45	28	1.59	0.262	623	50.8	3.09	623	1.55	0.294	< 0.05	> 0.25
Mean	566	53.5	4.14	514	1.73	0.404	1,653	52.2	3.77	1,545	1.69	0.381	< 0.001	< 0.05
Probability of difference	< 0.001			< 0.001			< 0.001			< 0.001				

1. Dashes indicate data not recorded.

TABLE 11. Fork lengths and weights of male and female, 2-sea-winter, virgin Atlantic salmon from the Big Salmon River, 1965-73.[1]

	Male						Female						Probability of difference	
	Length (cm)			Weight (kg)			Length (cm)			Weight (kg)				
Year	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	Length	Weight
1965[2]	1	73.7	-	-	-	-	0	-	-	-	-	-	-	-
1967[2]	5	74.7	2.90	-	-	-	21	74.8	3.73	-	-	-	> 0.75	-
1968	6	70.2	6.94	2	3.15	-	47	71.3	4.16	30	3.89	0.80	> 0.50	-
1969	3	67.0	1.00	3	3.18	0.23	31	70.7	4.88	31	4.10	0.91	> 0.10	> 0.05
1970	1	77.0	-	1	3.60	-	8	73.6	5.34	8	4.25	0.88	-	-
1971	1	73.0	-	1	3.80	-	1	65.0	-	1	3.80	-	-	-
1972	1	64.0	-	1	3.40	-	3	71.0	8.89	3	4.00	0.92	-	-
1973	1	66.0	-	1	3.30	-	3	76.0	1.73	3	4.83	0.67	-	-
Mean	19	71.0	5.36	9	3.33	0.34	114	72.0	4.72	76	4.05	0.85		
Probability of difference		> 0.25			> 0.75			< 0.01			> 0.50			

1. Data according to sex unavailable for 1966.

2. Weight data unavailable for 1965 and 1967.

TABLE 12. Fork lengths and growth increments, according to sea-age and spawning history, of male and female Atlantic salmon from the Big Salmon River, 1965-73.[1]

Sea-age and spawning history	Male				Female				Probability of difference
	n	$\bar{x}$(cm)	SD	$\Delta\ell$[2] (cm)	n	$\bar{x}$(cm)	SD	$\Delta\ell$[2] (cm)	
1.0	566	53.5	4.15	39.5[3]	1,093	52.9	3.90	38.9[3]	< 0.005
2.1	219	65.7	5.15	12.2	454	63.1	4.54	10.2	< 0.001
3.12	93	75.0	5.30	9.3	390	71.9	4.50	8.8	< 0.001
4.123	15	77.4	6.07	2.4	174	78.1	4.09	6.2	> 0.50
5.1234	0	-	-		45	83.1	4.76	5.0	-
6.12345	0	-	-		7	83.5	4.40	0.4	-
7.123456	0	-	-		1	88.0	-		-
2.0	15	71.2	5.26	57.2[3]	117	71.6	5.29	57.6[3]	> 0.75
3.2	16	74.4	7.01	2.3	99	77.5	5.07	6.6	< 0.05
4.23	2	82.0	-		23	81.6	5.03	4.1	-
5.234	1	91.4	-		4	81.6	7.72	0.0	-
3.0	2	85.5	-	71.5	8	76.0	2.73	62.0	-

1. Data for 1966 excluded.

2. Length at age "a" minus length at age "a-1" or to smolt length.

3. Mean smolt length for years 1966-72, excluding 1967, was used, with the assumption of no difference in length between sexes (Jessop 1975).

TABLE 13. Weight and growth increments according to sea-age and spawning history, of male and female Atlantic salmon from the Big Salmon River, 1968-73.

Sea-age and spawning history	Male				Female				Probability of difference
	n	$\bar{x}$(kg)	SD	$\Delta\omega^1$ (kg)	n	$\bar{x}$(kg)	SD	$\Delta\omega^1$ (kg)	
1.0	511	1.73	0.404	1.46[2]	985	1.77	0.402	1.50[2]	> 0.05
2.1	170	3.17	0.824	1.44	378	2.96	0.661	1.19	< 0.005
3.12	67	4.31	0.734	1.14	328	4.21	0.810	1.25	> 0.75
4.123	13	5.15	1.031	0.84	161	5.22	0.899	1.01	> 0.75
5.1234	0	-	-		37	6.03	1.040	0.81	-
6.12345	0	-	-		6	5.97	1.090		-
7.123456	0	-	-	[2]	1	6.90	-	[2]	-
2.0	9	3.33	0.340	3.06[2]	79	3.98	0.919	3.71[2]	< 0.05
3.2	9	4.58	1.386	1.47	80	4.96	0.908	1.10	> 0.25
4.23	1	6.58	-		21	5.71	0.917	0.75	-
5.234	0	-	-		3	6.13	1.041		-
3.0	2	5.67	-	5.40	6	4.84	0.318	4.57	-

1. Weight at age "a" minus weight at age "a-1", or to smolt weight.

2. Mean smolt weight for years 1966-72, excluding 1967, was used, with assumption of no difference in weight between sexes (Jessop 1975).

TABLE 14. Comparison of the fork lengths of 1-sea-winter and multi-sea-winter Atlantic salmon taken at the counting fence and in the angling fishery, Big Salmon River, 1968-73.

Year	1-sea-winter							Multi-sea-winter						
	Fence			Angled			Prob. of dif.	Fence			Angled			Prob. of dif.
	n	$\bar{x}$(cm)	SD	n	$\bar{x}$(cm)	SD		n	$\bar{x}$(cm)	SD	n	$\bar{x}$(cm)	SD	
1968	459	52.5	3.21	34	53.4	2.86	> 0.10	512	68.8	7.70	44	69.5	8.58	> 0.25
1969	13	51.9	4.91	26	52.9	3.98	> 0.25	350	67.8	7.55	138	67.9	7.09	> 0.75
1970	265	49.4	3.29	103	50.4	3.42	< 0.01	399	72.5	5.88	72	72.9	6.80	> 0.50
1971	232	52.3	3.14	99	52.0	3.62	> 0.25	165	73.9	8.88	31	70.5	8.08	< 0.001
1972	491	55.3	3.29	32	56.4	3.66	> 0.05	56	69.2	8.81	8	77.1	9.36	< 0.025
1973	90	51.2	2.95	38	51.8	3.87	> 0.25	55	70.5	5.67	13	70.5	7.94	> 0.50
Weighted mean	1,550	52.78	3.827	332	52.12	3.918	< 0.005	1,537	70.16	7.669	306	69.91	7.746	> 0.50
Unweighted mean	6	52.13	1.919	6	52.82	2.036	> 0.50	6	70.13	2.477	6	71.30	3.274	> 0.50

TABLE 15. Comparison of the marine growth in length of Atlantic salmon, originating as smolts of different ages and returning after 1-SW to the Big Salmon River, 1967-73.

Year of smoltification	Length (cm) of age-2 smolts			Length (cm) of age-3 smolts		
	As smolts	At 1-SW	Growth	As smolts	At 1-SW	Growth
1966	15.5	53.9	38.4	14.9	56.9	42.0
1968	15.0	53.3	38.3	15.2	49.7	34.5
1969	14.6	49.0	34.4	14.9	49.8	34.9
1970	12.9	52.1	39.2	13.9	53.2	39.3
1971	12.4	54.6	41.9	14.3	56.1	41.8
1972	13.1	51.0	37.9	14.4	51.5	37.1
Mean	13.25	52.27	38.35	14.33	53.34	38.27
SD	1.412	3.86	2.41	1.24	4.37	3.30
n	1,268	543	6	1,347	418	6

TABLE 16. Comparison of the marine growth in length of Atlantic salmon originating as smolts of different ages and returning as 2-sea-winter, virgin fish to the Big Salmon River.

Year of smoltification	Length (cm) of age-2 smolts			Length (cm) of age-3 smolts		
	As smolt	As 2-SWV	Growth	As smolts	As 2-SWV	Growth
1960	15.5	70.7	54.5	14.9	70.4	55.5
1967[1]	-	70.5	-	-	69.7	-
1968	15.0	75.3	60.3	15.2	73.0	57.8
1970	12.9	61.4	48.5	13.9	-[2]	-
Mean	14.19	69.69	54.43	14.32	70.34	56.65
SD	1.46	7.07	5.90	1.34	5.97	-
n	375	49	3	363	53	2

1. Smolt age composition unavailable.

2. Sample size inadequate.

TABLE 17. Comparison of the mean age at smoltification of Atlantic salmon collected as smolts and as 1- and 2-sea-winter virgin fish from the Big Salmon River, 1963-72.[1]

Year of smoltification	Mean age at smoltification									Probability of difference		
	Smolt			1-SW			2-SW					
	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	Smolt vs. 1-SW	Smolt vs. 2-SW	1-SW vs. 2-SW
1963	-	-	-	23	2.83	0.39	-	-	-	-	-	-
1964	-	-	-	69	2.61	0.49	-	-	-	-	-	-
1965	-	-	-	119	2.42	0.50	28	2.39	0.50	-	-	>0.75
1966	200	2.29	0.46	31	2.71	0.46	56	2.52	0.50	<0.001	<0.005	<0.025
1967	203	2.69	0.52	439	2.59	0.52	32	2.59	0.50	<0.025	>0.25	>0.75
1968	245	2.37	0.48	14	2.93	0.73	9	2.56	0.53	<0.001	>0.10	>0.10
1969	182	2.49	0.51	254	2.50	0.51	-	-	-	>0.75	-	-
1970	990	2.65	0.52	196	2.26	0.44	-	-	-	<0.001	-	-
1971	1,345	2.71	0.60	279	2.45	0.50	-	-	-	<0.001	-	-
1972	565	2.34	0.48	92	2.46	0.50	-	-	-	<0.05	-	-
Mean	3,730	2.58	0.56	1,616	2.50	0.51	125	2.51	0.50			
Probability of difference	<0.001			<0.001			>0.25					

1. Dashes indicate data unavailable or fewer than five fish in sample.

TABLE 18. Age composition of untagged Atlantic salmon smolts departing and of grilse returning the next year to the Big Salmon River, and survival rates for each group, 1966-71.

Year of smoltification	Smolt age	Smolt[1] No.	Smolt[1] % total	Grilse[1,2] No.	Grilse[1,2] % total	Smolt to grilse Survival rate(%)	Smolt to grilse Mortality(Z)
1966	2	13,226	72.0	206	26.5	1.6	
	3	5,052	27.5	504	64.7	10.0	
	4	92	0.5	69	8.8	75.0	
	Totals	18,370		779		$\bar{x}$ 4.2	3.16
1967	2	2,429	33.5	511	42.2	21.0	
	3	4,604	63.5	681	56.4	14.8	
	4	217	3.0	18	1.5	8.3	
	Totals	7,250		1,210		$\bar{x}$ 16.7	1.79
1968	2	10,467	62.9	57	33.1	0.5	
	3	6,173	37.1	102	59.3	1.7	
	4	--	--	13	7.6	--	
	Totals	16,640		172		$\bar{x}$ 1.0	4.57
1969	2	4,925	51.1	215	50.4	4.4	
	3	4,665	48.4	210	49.3	4.5	
	4	48	0.5	1	0.3	2.1	
	Totals	9,638		426		$\bar{x}$ 4.4	3.12
1970	2	7,274	36.8	369	77.5	5.1	
	3	12,097	61.2	107	22.5	0.9	
	4	395	2.0	0	0.0	0.0	
	Totals	19,766		476		$\bar{x}$ 2.4	3.73
1971	2	6,692	36.4	522	52.5	7.8	
	3	10,295	56.0	473	47.5	4.6	
	4	1,397	7.6	0	0.0	0.0	
	Totals	18,384		995		$\bar{x}$ 5.4	2.92
Total	2	45,013	50.0	1,893	46.6	4.2	
	3	42,886	47.6	2,077	51.2	4.8	
	4	2,149	2.4	88	2.2	4.1	
	Grand mean						3.20
Overall survival		90,048		4,058		4.5	

1. Smolt numbers at age derived from Tables 1 and 8 and Appendix B (Jessop 1975).

2. Age composition based on aged sample data applied to grilse identified as such by weight.

3. 1970-71 grilse data include estimate of fish angled downstream of fence.

TABLE 19. Survival rates between smoltification and 1-sea-winter return for Atlantic salmon released as tagged and untagged smolts to the Big Salmon River, 1967-71.

Year of smoltification	No. of smolts tagged [1]	No. of 1-SW returns	Percent survival	No. of smolts untagged [2]	No. of 1-SW returns	Percent survival
1967	3,900	33	0.8	7,250	1,210	16.7
1968	5,120	3	0.1	16,640	172	1.0
1969	3,792	4	0.1	9,638	426	4.4
1970	9,864	5	0.1	19,766	476	2.4
1971	7,786	44	0.6	18,384	995	5.4
Mean survival			0.3			4.2

1. Tagged smolt numbers are from Appendix B (Jessop 1975).

2. Untagged total equals estimated total smolt run minus smolts tagged; similarly for 1-SW fish.

TABLE 20. Sex composition of 1-sea-winter Atlantic salmon returning to the Big Salmon River counting fence, 1965-73.[1]

Year	No. of males	No. of females	% male : % female
1965	20	49	29:71
1967	17	17	50:50
1968	163	298	35:65
1969	9	5	64:36
1970	107	157	41:59
1971	79	153	34:66
1972	143	352	29:71
1973	28	62	31:69
Totals	566	1,093	34:66

1. Data unavailable for 1966.

TABLE 21. Sex composition of Atlantic salmon returning to the Big Salmon River counting fence compared with that of the angling catch, 1965-73. [1]

	Counting fence			Angling catch		
Year	No. of males	No. of females	% male:% female	No. of males	No. of females	% male: % female
1965	32	86	27:73	-	-	-
1967	60	110	36:64	-	-	-
1968	217	543	29:71	30	50	38:62
1969	101	267	27:73	47	124	27:73
1970	177	490	29:71	55	122	31:69
1971	108	305	26:74	41	98	29:71
1972	103	266	28:72	13	27	33:67
1973	47	117	29:71	12	40	23:77
Totals	845	2,184	28:72	198	461	30:70

1. Data unavailable for 1966.

TABLE 22. Summary of the numbers of Atlantic salmon tagged at the counting fence, released and recaptured in the Big Salmon River.

		Subsequent adult recaptures				
Year	No. tagged	1-SW	2-SW	3-SW	4-SW	5-SW
Smolts						
1967	3,900	35	23	10	1	1
1968	5,120	3	1			
1969	3,792	3	1			
1970	9,864	5	1			
1971	7,786	43	4	1		
Mean % recovery		0.29	0.10	0.04	< 0.01	< 0.01
1-SW salmon						
1970	63	3	3			
1973	65	5				
Mean % recovery		6.3	2.3			

TABLE 23. Relationships between adult spawning escapement and subsequent smolt production for Atlantic salmon from the Big Salmon River, 1964-73.

Year	Escapement[1]	% female[1]	Potential egg deposition[1] x 10[3]	Egg deposition/ 1-m² rearing area[4]	Egg deposition/ 1-m² spawning area	Smolt emigration[5]	Smolt yield/ 100-m² rearing area[4]	% egg-to-smolt survival
1964	1,961	72.1	7,680	16.5	298	11,900	2.55	0.16
1965	3,496	72.9	14,607	31.4	930	20,800	4.47	0.14
1966	4,447	72.1	12,560	27.0	800	27,000	5.81	0.21
1967	3,110	64.7	14,205	30.6	905	25,700	5.52	0.17
							$\bar{x}$ = 4.59	$\bar{x}$ = 0.17
1968	2,531	71.4	8,435	18.1	537			
1969	1,274	72.6	5,353	11.5	341			
1970	1,114	73.5	4,573	9.8	291			
1971	805	73.8	3,126	6.7	199			
1972	1,191	72.1	2,883	6.2	184			
1973	671	71.3	1,982	4.3	126			

1. From Table 1.

2. Based on counting fence data; data unavailable for 1964 and 1966, so mean of other years was used (Jessop 1975).

3. Based on female length-frequency distribution and corrected length-fecundity relationship by Glebe et al. (1979) and Glebe (pers. comm. 1983), ($Y=177.77e^{0.09X}$ where Y=fecundity, X=fork length [cm]). Length-frequency distribution for combined sexes used in 1964 and 1965.

4. Accessible rearing area of 464,900 m²; spawning area of 15,700 m² (Jessop 1975).

5. Derived from adjusted smolt numbers and age compositions of Tables 1 and 8 in Jessop (1975); 1972 age-4 component of 1970 year-class was derived from the observed smolt-age composition applied to the mean 1966-71 adjusted smolt count.

APPENDICES

APPENDIX A

LENGTHS (cm) - ACCORDING TO YEAR OF RETURN, SEA-WINTER AGE, SPAWNING HISTORY AND SEX - OF ATLANTIC SALMON RECORDED AT THE BIG SALMON RIVER COUNTING FENCE, 1965-73.

Sea-age and spawning history	1965			1967			1968			1969			1970		
	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD
Male															
1.0	20	59.2	2.98	17	56.3	3.38	163	53.2	3.39	9	53.6	4.90	107	50.2	3.39
2.1	3	69.4	3.88	17	66.8	4.09	75	65.6	4.87	70	66.1	5.80	19	63.6	6.42
3.12	4	79.4	7.59	15	78.2	4.32	19	74.6	5.28	13	77.0	6.82	38	73.3	3.36
4.123				1	78.7	-				2	81.5	9.19	2	75.0	4.24
2.0				5	74.7	2.90	5	68.6	6.47	3	67.0	1.00	1	77.0	-
3.2				1	68.6	-	9	75.3	5.75	2	64.5	3.54	4	78.8	7.00
4.23							1	78.0	-	1	86.0	-			
5.234				1	91.4	-									
3.0							2	85.5	-						
Female															
1.0	49	57.6	3.38	17	55.7	6.06	296	52.2	3.05	4	48.3	2.50	157	48.9	3.13
2.1	8	69.5	7.05	19	65.8	2.66	193	62.7	3.70	143	63.0	4.60	21	63.4	6.00
3.12	8	77.2	5.91	35	75.7	3.36	67	70.5	4.38	46	70.8	4.47	190	70.6	2.94
4.123	6	85.5	3.82	3	77.0	6.39	27	79.9	3.30	10	78.3	4.37	53	76.5	3.71
5.1234	2	86.4	3.59	5	86.9	3.31	12	83.7	6.08	3	85.7	1.53	10	81.4	3.89
6.12345				1	86.4	-				2	80.5	4.95	1	78.0	-
7.123456													1	88.0	-
2.0	1	73.7	-	21	74.7	3.73	48	70.9	4.81	31	70.4	5.55	8	73.6	5.34
3.2	5	82.3	4.25	5	81.3	4.40	35	77.0	5.70	12	76.3	4.71	39	77.6	3.52
4.23	1	66.0	-	1	86.4	-				12	81.4	4.32	7	83.1	3.24
5.234	1	81.3	-										3	81.7	9.45
3.0							8	76.0	2.73						

APPENDIX A (CONTINUED)

Sea-age and spawning history	1971			1972			1973			Grand mean			Probability of difference between years
	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	
Male													
1.0	79	52.5	3.31	143	55.9	3.88	28	52.1	2.45	566	53.5	4.15	
2.1	10	63.4	5.78	13	64.1	3.33	12	68.3	6.42	219	65.7	5.15	< 0.01
3.12	4	69.0	6.73							93	75.0	5.30	> 0.05
4.123	9	78.3	4.73	1	64.0	-				15	77.4	6.07	< 0.005
2.0	1	73.0	-										
3.2										15	71.2	5.26	
4.23										16	74.4	7.01	> 0.05
5.234										2	82.0	-	
										1	91.4	-	
3.0										2	85.5	-	
Female													
1.0	153	52.2	3.06	352	55.1	2.98	63	50.8	3.06	1,093	52.9	3.90	
2.1	24	58.7	3.74	21	63.4	5.32	25	66.9	3.43	454	63.1	4.54	< 0.001
3.12	27	77.9	4.94	5	74.8	8.17	12	75.1	3.97	390	71.9	4.50	< 0.001
4.123	67	77.5	3.55	8	81.4	3.42				174	78.1	4.09	< 0.001
5.1234	13	81.2	4.08							45	83.1	4.76	< 0.001
6.12345	1	89.0					2	85.0	-	7	83.5	4.40	> 0.10
7.123456										1	88.0	-	
2.0	2	61.5	4.95	3	71.0	8.89	3	76.0	1.73	117	71.6	5.29	
3.2	2	77.7	13.32	1	65.0	-				99	77.5	5.07	< 0.005
4.23	2	82.5	2.12							23	81.6	5.03	> 0.05
5.234										4	81.6	7.72	
3.0										8	76.0	2.73	

APPENDIX B

WEIGHTS (kg) - ACCORDING TO YEAR OF RETURN, SEA-WINTER AGE, SPAWNING HISTORY AND SEX - OF ATLANTIC SALMON RECORDED AT THE BIG SALMON RIVER COUNTING FENCE, 1968-73

Sea-age and spawning history	1968			1969			1970			1971		
	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD
Male												
1.0	148	1.68	0.265	9	1.65	0.377	107	1.42	0.333	79	1.59	0.271
2.1	48	3.04	0.685	69	3.18	0.904	19	3.07	0.876	10	3.01	0.702
3.12	12	4.37	0.385	13	4.45	1.332	38	4.30	0.503	4	3.83	0.818
4.123				2	5.16	1.363	2	4.75	1.061	9	5.23	1.084
2.0	2	3.2	0.636	3	3.20	0.230	1	3.6	-	1	3.80	-
3.2	3	4.80	0.954	2	2.95	0.962	4	5.23	1.353			
4.23				1	6.58	-						
5.234												
3.0	2	5.67	-									
Female												
1.0	255	1.65	0.235	5	1.52	0.317	157	1.37	0.322	153	1.67	0.311
2.1	144	2.88	0.469	143	2.96	0.734	21	3.10	0.718	24	2.46	0.495
3.12	48	3.98	0.726	46	3.95	0.781	190	4.09	0.586	27	5.41	0.981
4.123	23	5.73	1.261	10	5.26	0.879	53	4.96	0.715	67	5.14	0.747
5.1234	11	6.17	1.430	3	6.20	0.131	10	6.18	0.890	13	5.75	0.902
6.12345				2	5.50	1.042	1	4.90	-	1	7.10	-
7.123456							1	6.90	-			
2.0	31	3.83	0.844	31	4.10	0.905	8	4.25	0.880	2	3.05	1.061
3.2	25	4.89	0.742	12	4.61	1.004	39	5.17	0.838	3	4.80	1.952
4.23				12	5.48	0.857	7	5.99	1.054	2	6.15	0.707
5.234							3	6.13	1.041			
3	6	4.84	0.318									

APPENDIX B (CONTINUED)

Sea-age and spawning history	1972			1973			Grand mean			Probability of difference between years[1]
	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	
Male										
1.0	140	2.12	0.363	28	1.59	0.262	511	1.73	0.404	< 0.001
2.1	13	3.21	0.524	11	3.99	0.835	170	3.17	0.824	< 0.025
3.12							67	4.31	0.734	> 0.50
4.123							13	5.15	1.031	
2.0	1	3.40	-	1	3.30	-	9	3.33	0.340	
3.2							9	4.58	1.386	
4.23							1	6.58	-	
5.234										
3.0							2	5.67	-	
Female										
1.0	352	2.11	0.313	63	1.55	0.292	985	1.77	0.402	< 0.001
2.1	21	3.31	0.822	25	3.52	0.613	378	2.96	0.661	< 0.001
3.12	5	4.62	1.370	12	4.98	0.925	328	4.21	0.810	< 0.001
4.123	8	6.16	0.987				161	5.22	0.899	< 0.001
5.1234							37	6.03	1.040	> 0.50
6.12345				2	6.40	1.273	6	5.97	1.090	
7.123456							1	6.90	-	
2.0	3	4.00	0.917	4	4.05	1.658	79	3.98	0.919	> 0.25
3.2	1	3.20	-				80	4.96	0.908	> 0.10
4.23							21	5.71	0.917	> 0.25
5.234							3	6.13	1.041	
3							6	4.84	0.318	

1. Only years in which $n \geq 5$ were included.

APPENDIX C

ANALYSIS OF VARIANCE OF LENGTHS (cm) -
BY SEX AND YEAR - OF 1-SW ATLANTIC SALMON
FROM BIG SALMON RIVER, 1965-73[1]

Source of variation	df	SS	MS	F	Prob.
Main effects [2]	8	8,961.2			
Sex	1	224.8	224.8	21.3	<0.001
Year	7	7,894.3	1,127.7	106.8	<0.001
Interaction	7	100.8	14.4		
Error	1,638	17,295.4	10.6		
Total	1,653	26,357.4			

1. Data for 1966 are unavailable.
2. Uses method of weighted squares of means.

APPENDIX D

ANALYSIS OF VARIANCE OF WEIGHTS (kg) -
BY SEX AND YEAR - OF 1-SW ATLANTIC SALMON
FROM BIG SALMON RIVER, 1968-73

Source of variation	df	SS	MS	F	Prob.
Main effects [1]	6	107.34			
Sex	1	0.45	0.45		
Year (Adj.)	5	106.89	21.38	236.3	< 0.001
Year	5	107.28	21.46		
Sex (Adj.)	1	0.06	0.06	0.7	0.41
Interaction	5	0.55	0.11		
Error	1,482	134.08	0.09		
Total	1,493	241.97			

1. Uses method of fitting constants.

APPENDIX E

ANALYSIS OF VARIANCE OF LENGTHS (cm) -
BY SEX AND YEAR - OF 2-SW VIRGIN ATLANTIC SALMON
FROM BIG SALMON RIVER, 1965-73 [1]

Source of variation	df	SS	MS	F	Prob.
Main effects [2]	8	1,318.4			
Sex	1	76.6	76.6		
Year (Adj.)	7	1,241.8	177.4	5.4	< 0.001
Year	7	1,264.7	180.7		
Sex (Adj.)	1	53.7	53.7	1.6	0.20
Interaction	6	294.1	49.0		
Error	126	4,125.6	32.7		
Total	140	5,738.1			

1. Data for 1966 are unavailable.
2. Uses method of fitting constants.

APPENDIX F

ANALYSIS OF VARIANCE OF WEIGHTS (kg) -
BY SEX AND YEAR - OF 2-SW VIRGIN ATLANTIC SALMON
FROM BIG SALMON RIVER, 1968-73

Source of variation	df	SS	MS	F	Prob.
Main effects [1]	6	16.67			
Sex	1	6.90	6.90		
Year (Adj.)	5	9.77	1.95	2.25	0.06
Year	5	11.87	2.37		
Sex (Adj.)	1	4.80	4.80	5.52	0.02
Interaction	5	2.19	0.44		
Error	82	71.22	0.87		
Total	93	90.07			

1. Uses method of fitting constants.

APPENDIX G

ANALYSIS OF COVARIANCE OF WEIGHT-LENGTH RELATIONSHIPS (log_{10} transformed) - BY SEX AND AGE AT MATURITY - OF ATLANTIC SALMON FROM BIG SALMON RIVER, 1968-73

Source	df	SS	MS	F	Prob.
Male 1-SW	464	1.5109	0.0033		
Female 1-SW	635	1.9943	0.0031		
Male 2-SW	19	0.0436	0.0023		
Female 2-SW	198	0.5267	0.0027		
Pooled within	1,319	4.0976	0.0031		
Equality of slopes	3	0.0221	0.0074	2.34	> 0.05
Residual error	1,316	4.0755	0.0031		
Equality of adj. means	3	292.6984	97.5661	31,371.74	< 0.001
Residual error	1,319	4.0976	0.0031		
Total	1,322	296.7960			

APPENDIX H

WEIGHT-LENGTH RELATIONSHIPS - BY SEX AND AGE AT MATURITY - OF ATLANTIC SALMON FROM BIG SALMON RIVER, 1968-73[1]

			Geometric mean regression			Predictive regression		y means	
Group origin	n	r^2	Intercept	Slope	$S^2_{y.x}$	Intercept	Slope	Unadj.	Adj.
Male 1-SW	466	0.923	-4.7025	2.8568	0.0033	-4.5023	2.7443	0.382	0.458
Female 1-SW	637	0.948	-4.7024	2.8671	0.0031	-4.5649	2.7908	0.469	0.470
Male 2-SW	21	0.873	-4.9117	2.9644	0.0023	-4.5506	2.7705	0.608	0.457
Female 2-SW	200	0.778	-4.6920	2.8535	0.0027	-4.0605	2.5173	0.667	0.472
Combined	1,324	0.932	-4.7055	2.8637	0.0031	-4.4265	2.7647		

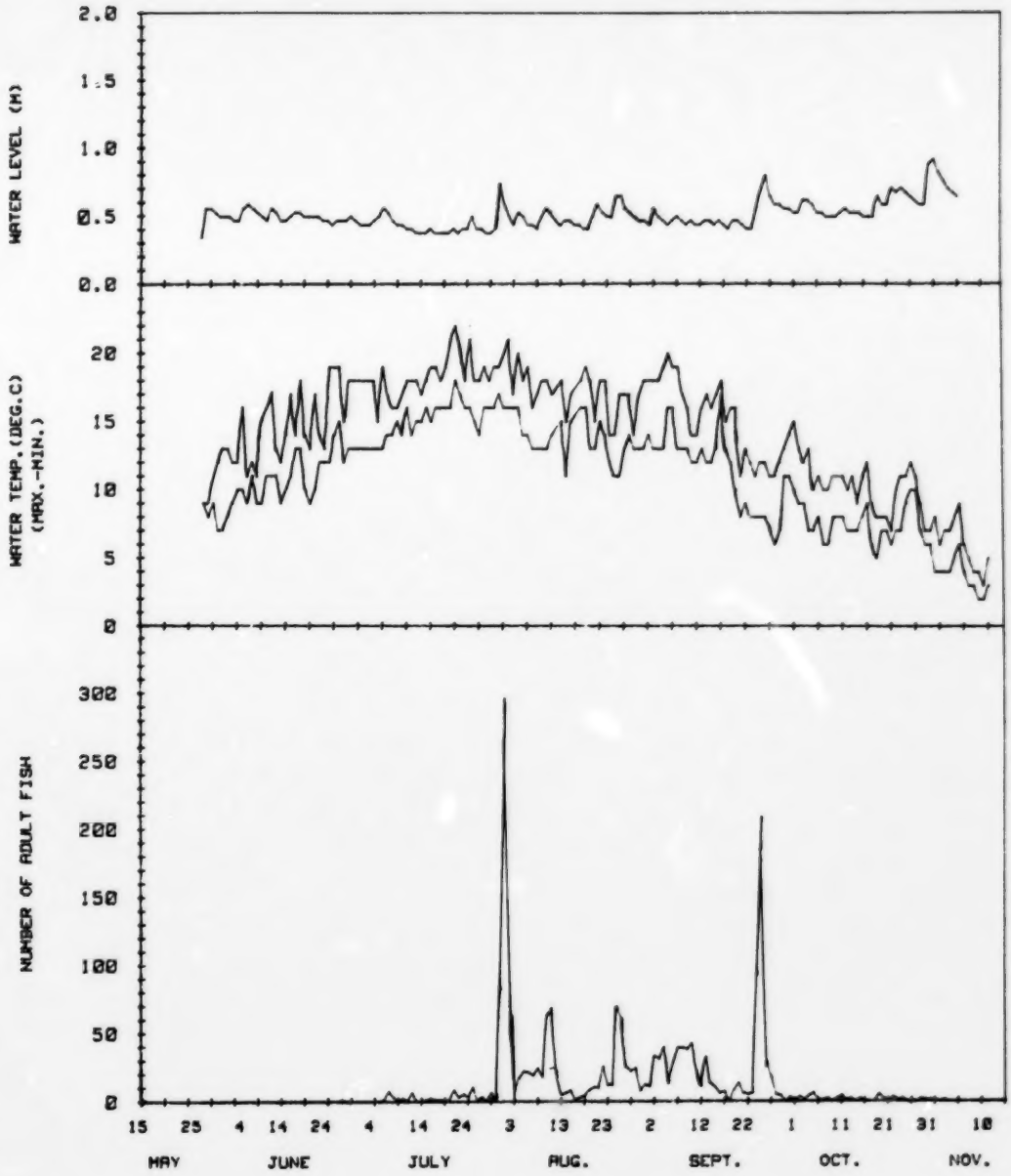
1. $Y=log_{10}$ weight; $X=log_{10}$ fork length.

APPENDIX I

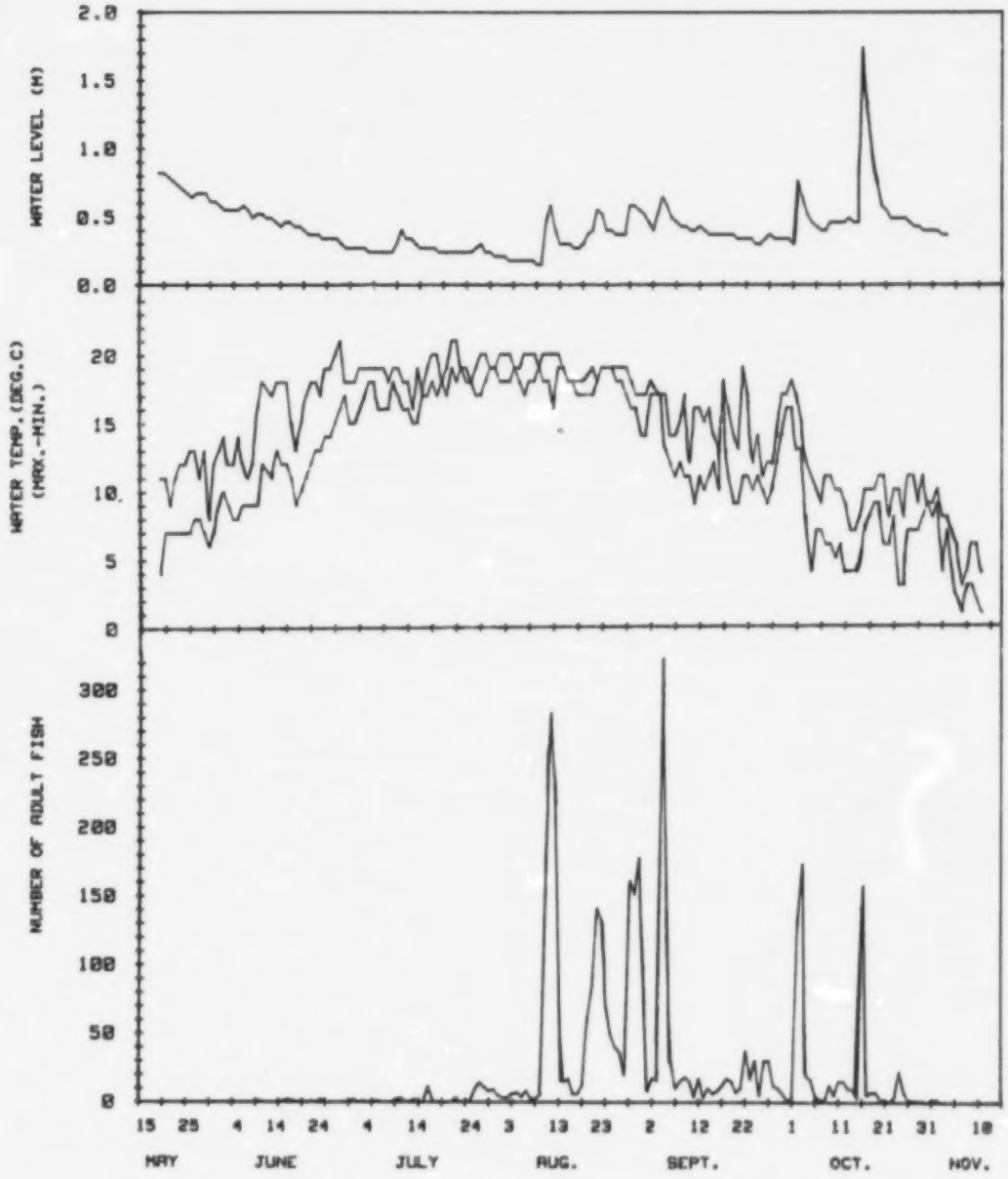
TWO-WAY ANALYSES OF VARIANCE OF FORK LENGTHS (cm) OF 1-SW AND M-SW ATLANTIC SALMON TAKEN AT THE BIG SALMON RIVER COUNTING FENCE AND IN THE ANGLING FISHERY, 1968-73

Source	df	SS	MS	F	P
1-sea-winter [1]					
Catch method	1	115.47	115.47		
Year (adj.)	5	7,353.41	1,470.68	135.34	0.01
Year	5	7,392.85	1,478.57		
Catch method (adj.)	1	76.03	76.03	7.00	0.01
Interaction	5	75.44	15.09	1.39	0.23
Error	1,870	20,321.12	10.87		
Multi-sea-winter [2]					
Catch method	1	96.93	96.93	1.79	0.18
Year	5	4,451.51	890.30	16.40	0.01
Interaction	5	766.36	153.27	2.82	0.02
Error	1,831	99,407.55	54.29		

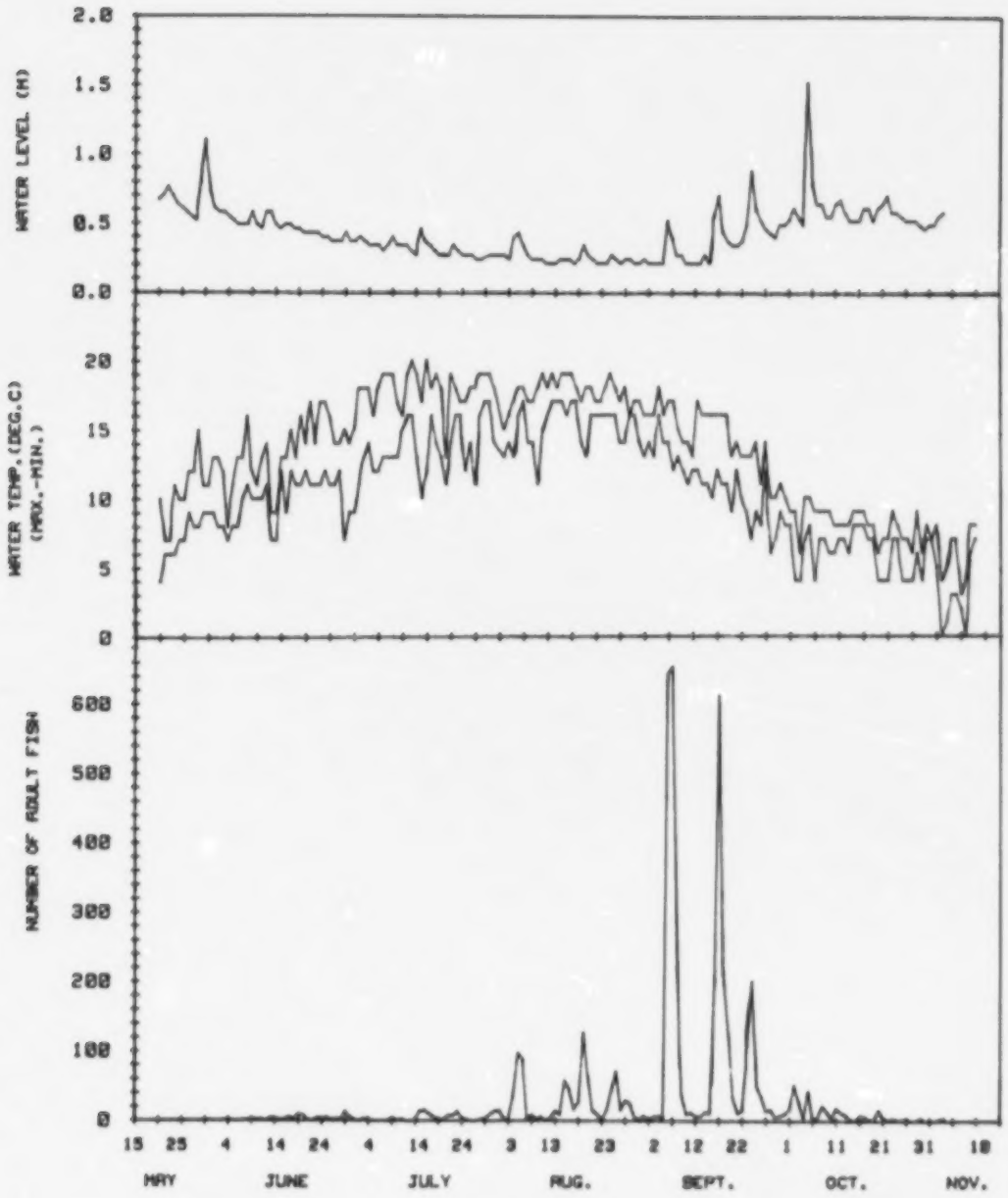
1. Method of fitting constants.
2. Method of weighted squares of means.



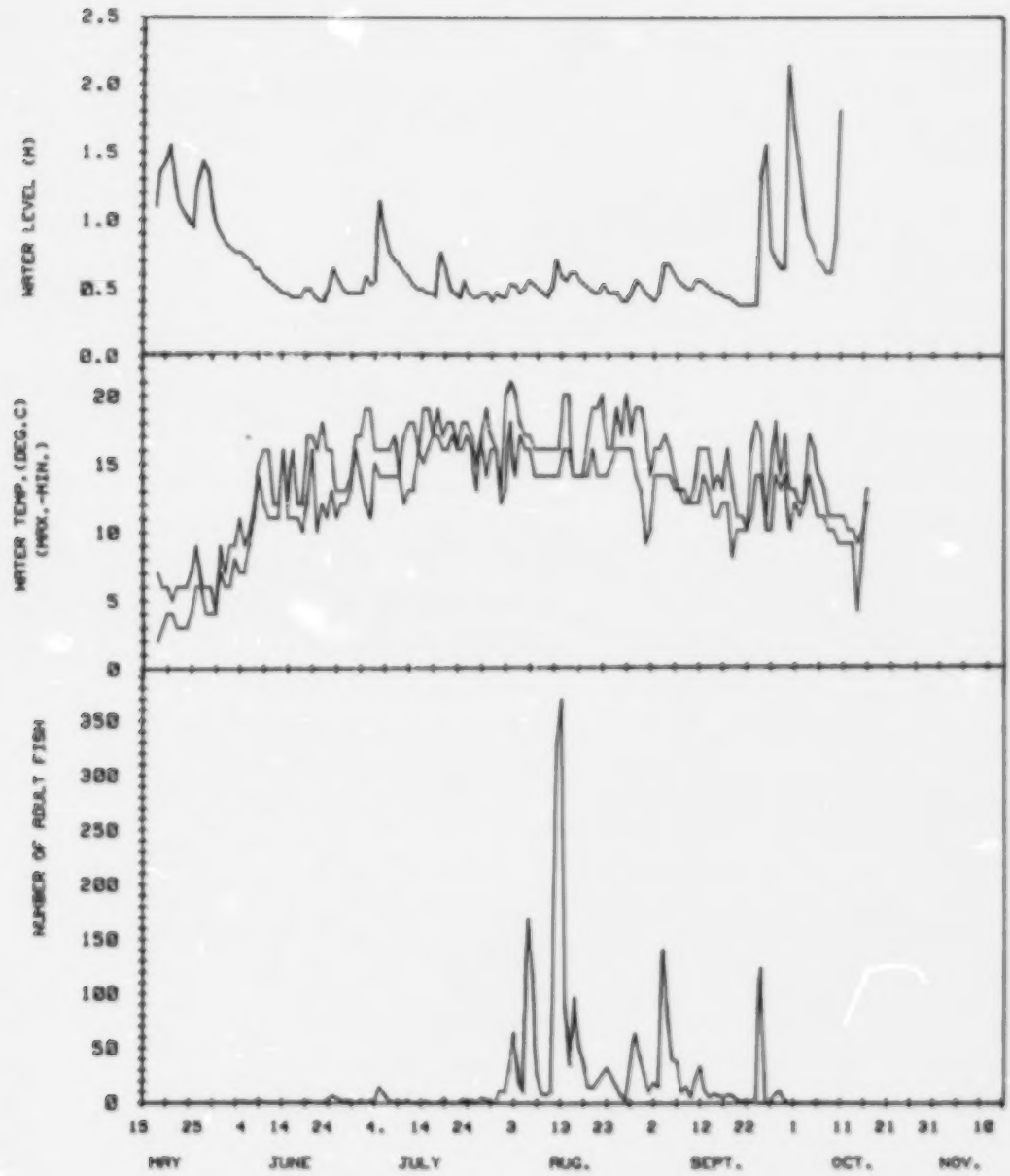
APPENDIX FIG. 1. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1964.



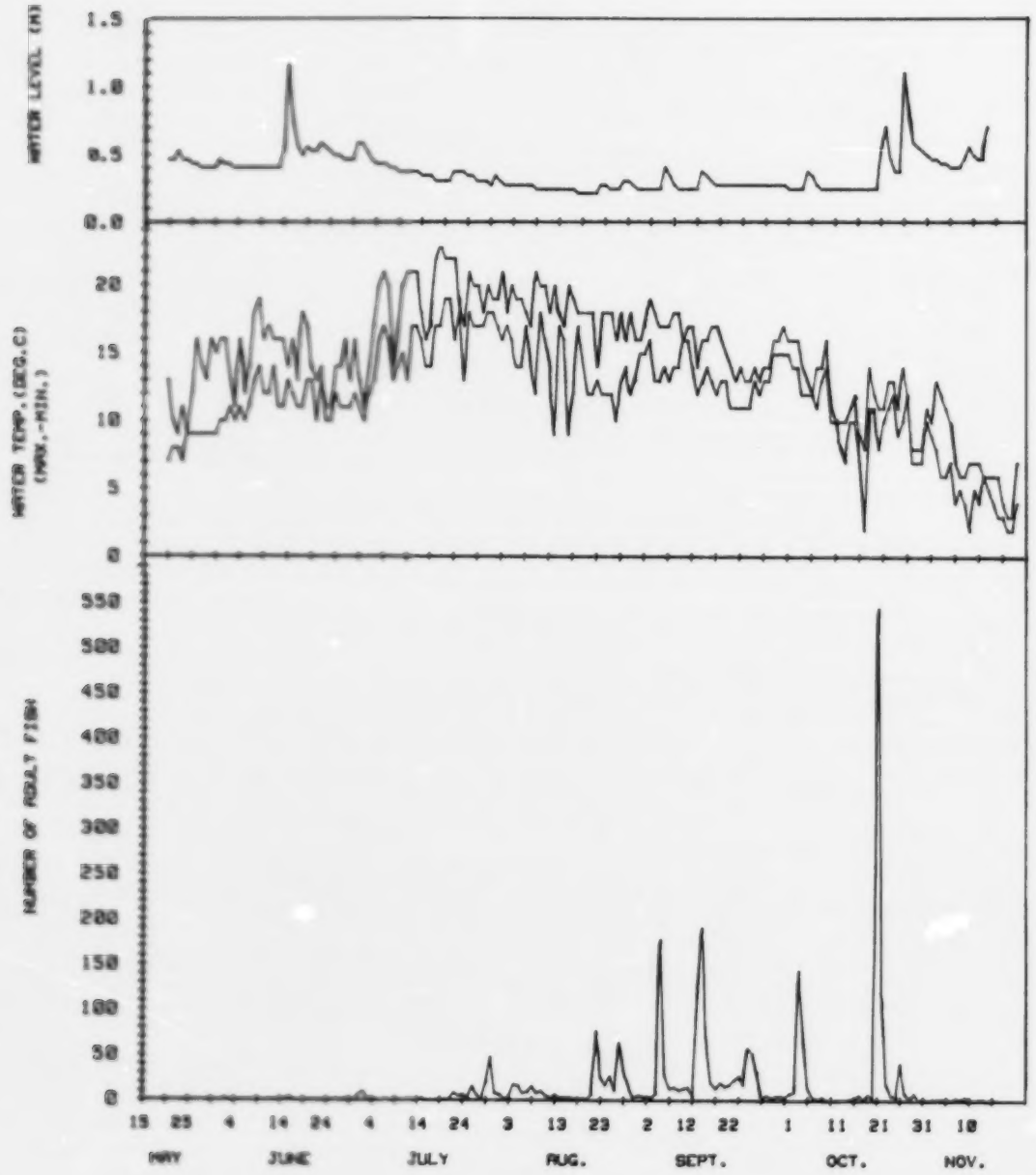
APPENDIX FIG. 2. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1965.



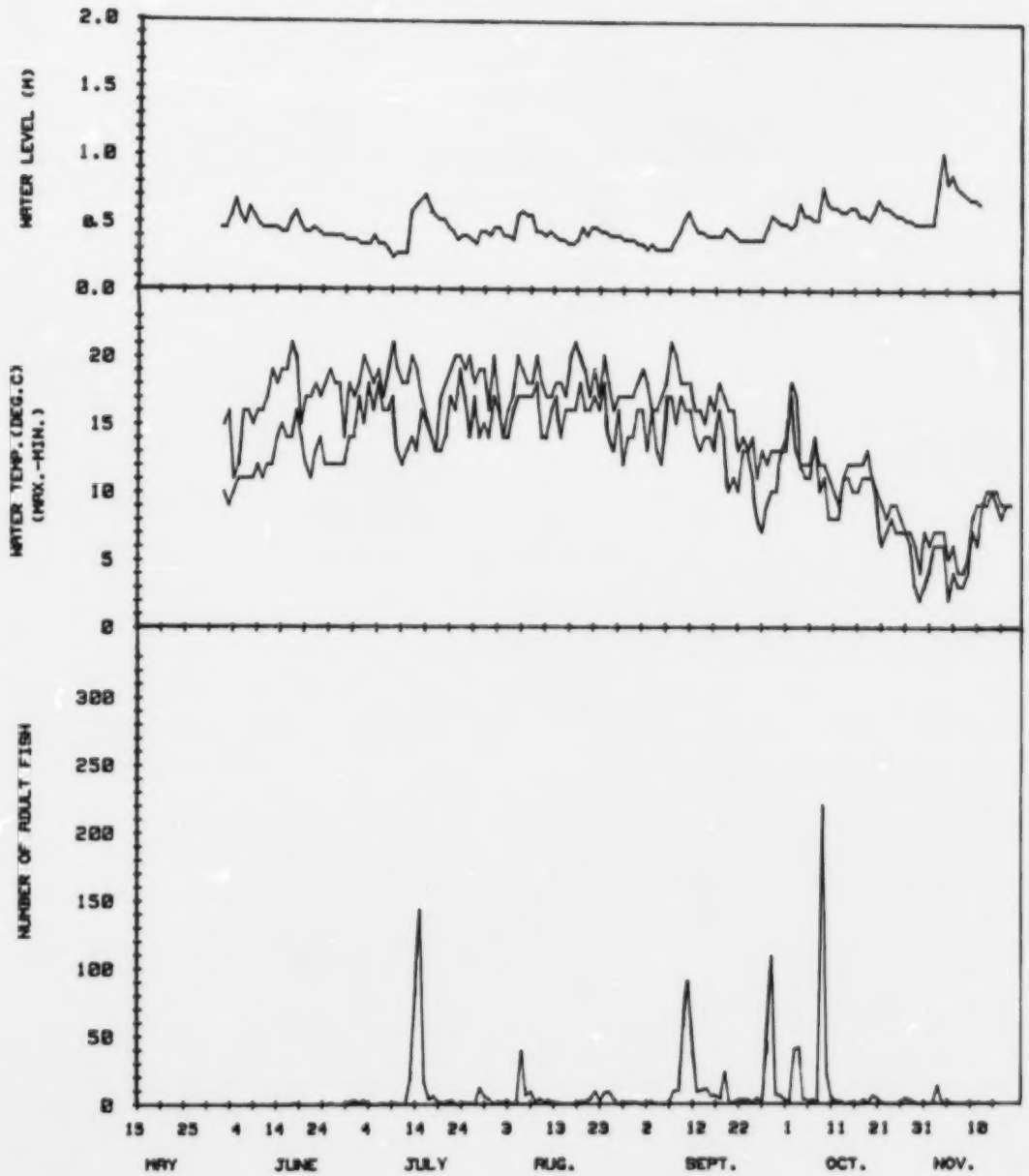
APPENDIX FIG. 3. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1966.



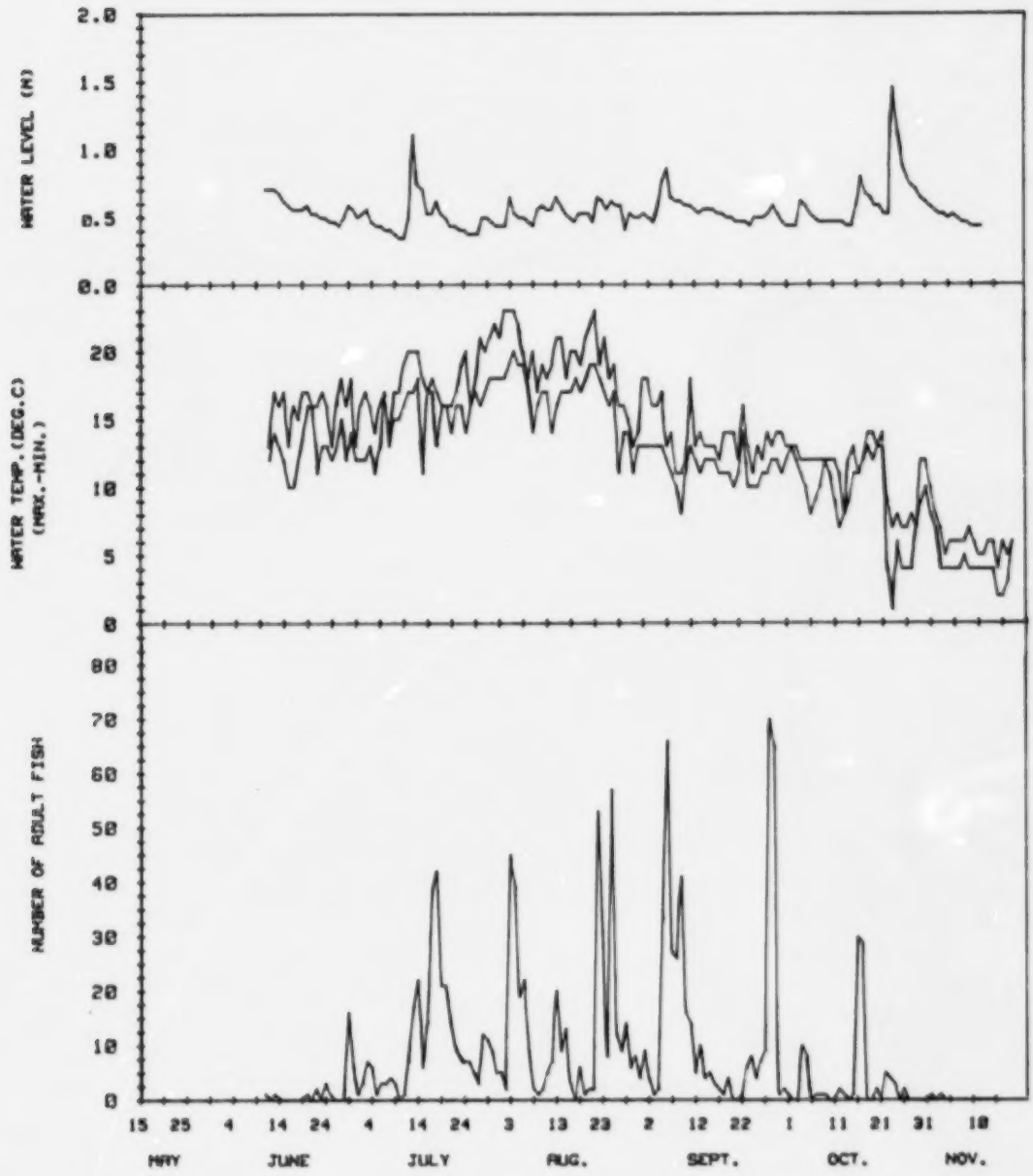
APPENDIX FIG. 4. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1967.



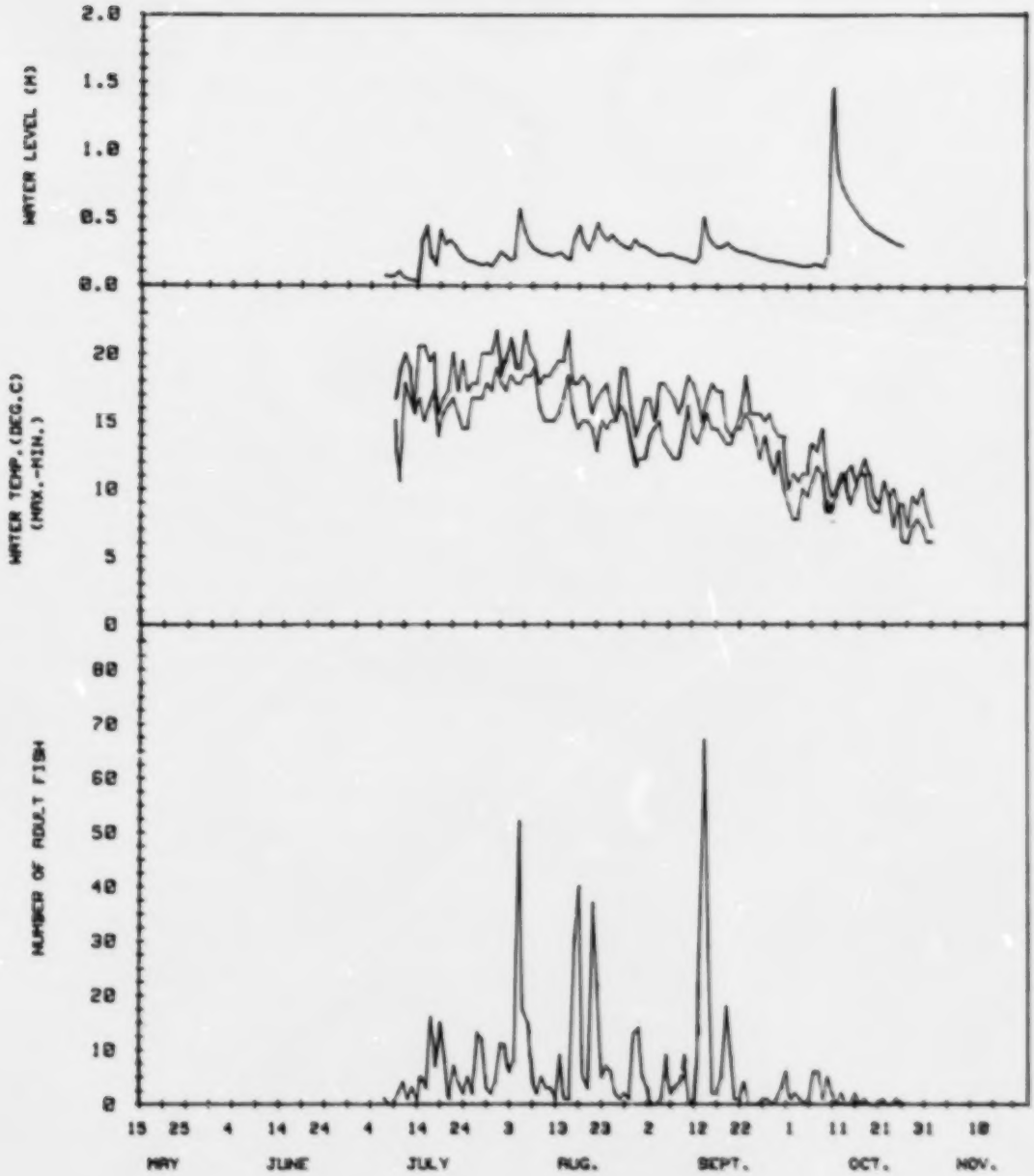
APPENDIX FIG. 5. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1968.



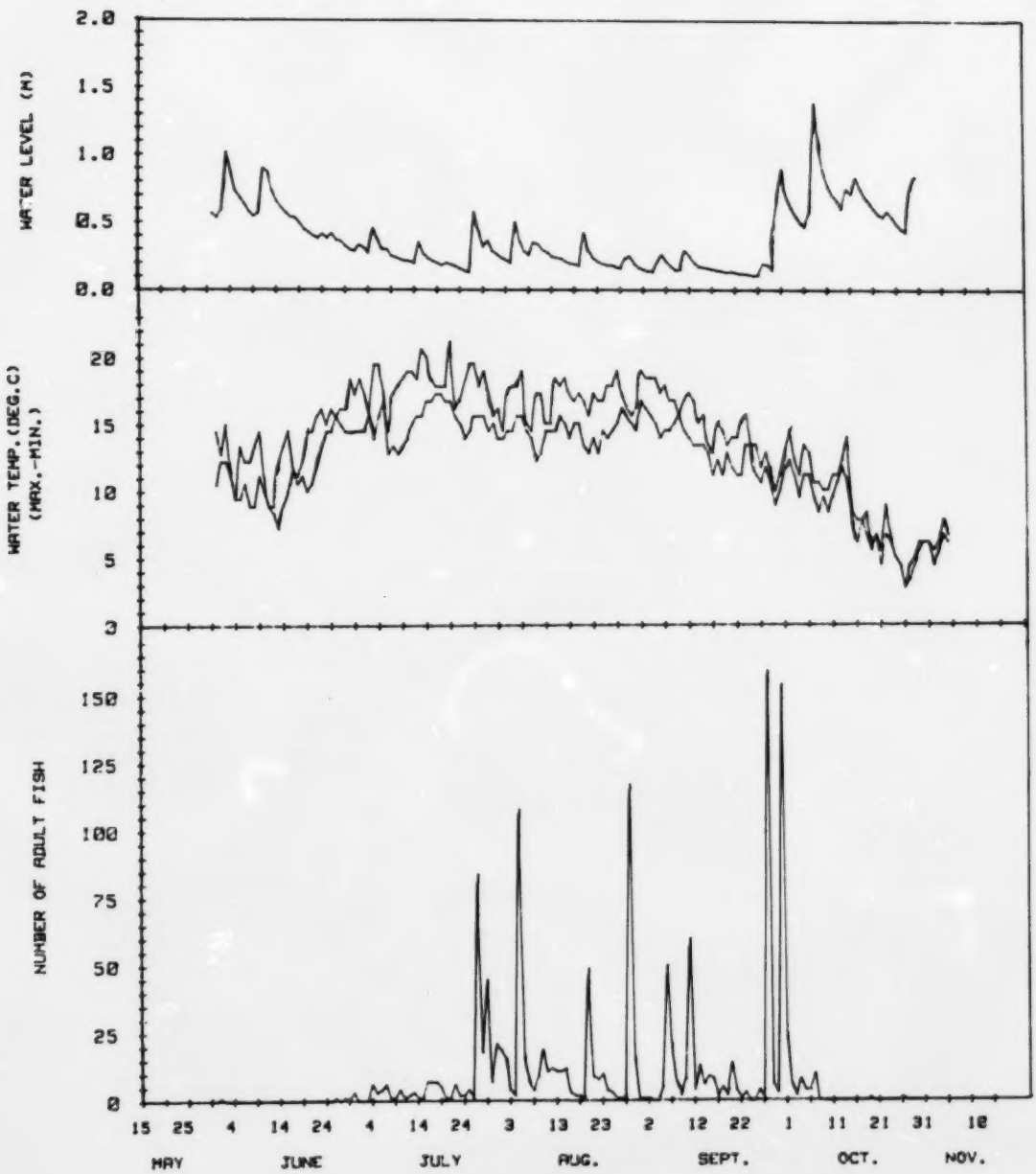
APPENDIX FIG. 6. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1969.



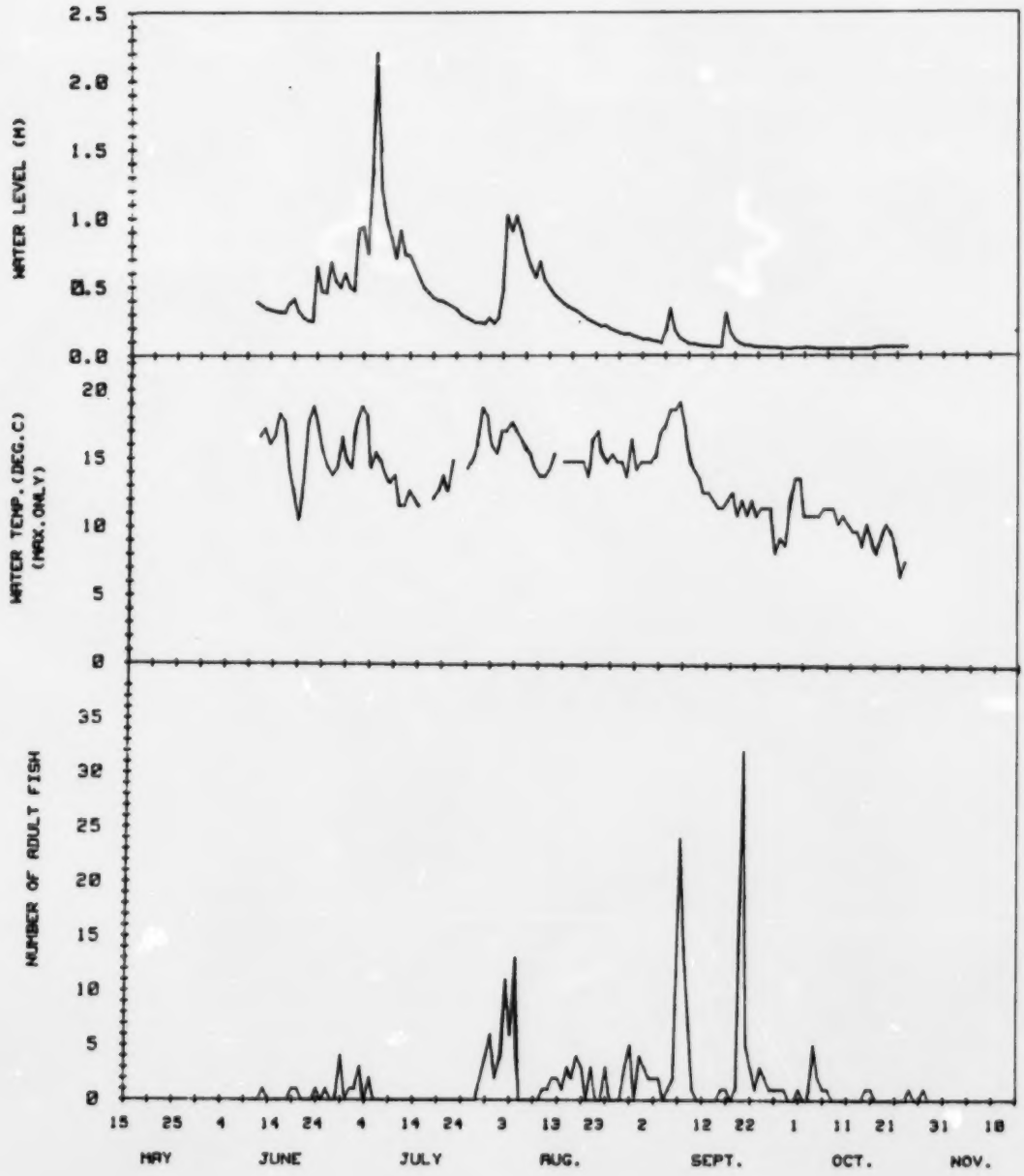
APPENDIX FIG. 7. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1970.



APPENDIX FIG. 8. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1971.



APPENDIX FIG. 9. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1972.



APPENDIX FIG. 10. Number of Atlantic salmon recorded daily at the counting fence, in relation to water temperature and level, Big Salmon River, 1973.

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